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NATIONAL GEOGRAPHIC

THE NEW COLD WAR

AS THE ICE MELTS, OLD RIVALS SCRAMBLE FOR POSITION

THE ARCTIC IS HEATING UP

THE CARBON THREAT

THAWING TUNDRA WILL SPEED UP GLOBAL WARMING



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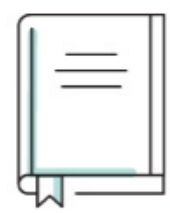
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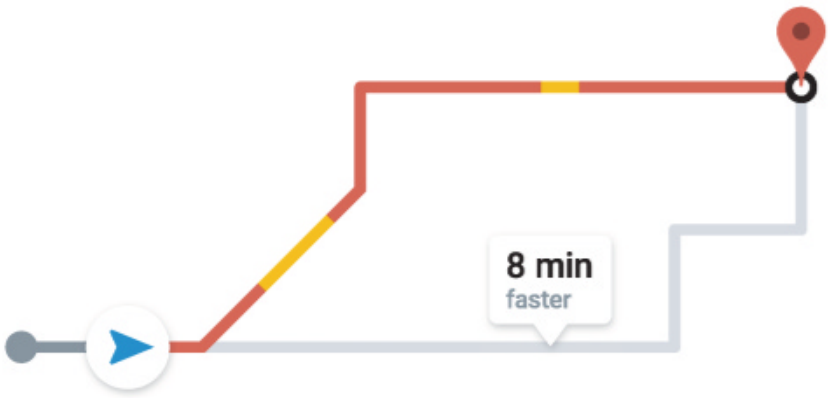
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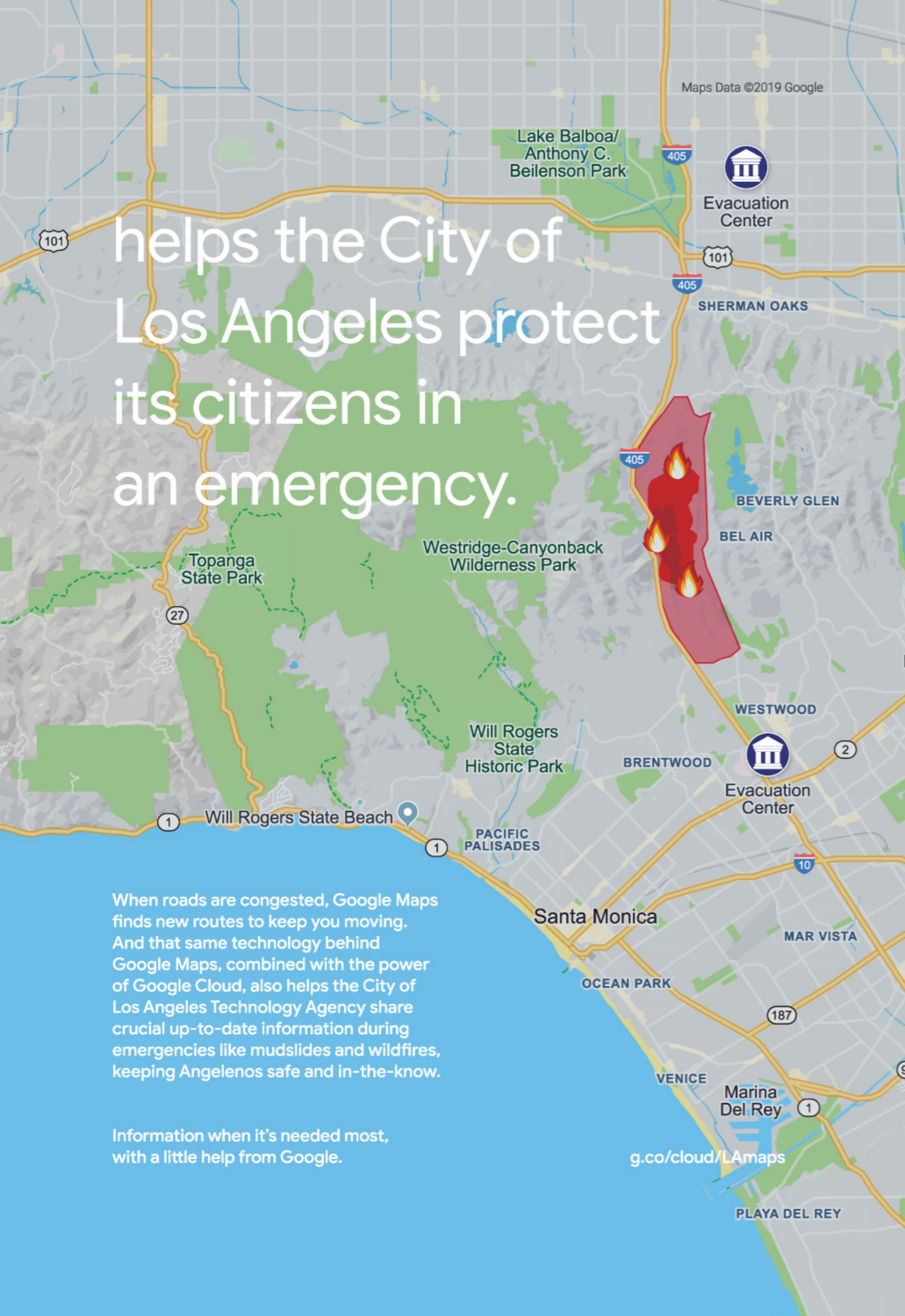
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Information when it's needed most, with a little help from Google.

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A FOOT OF WATER

NEVER FELT SO DEEP.

Cranberry River

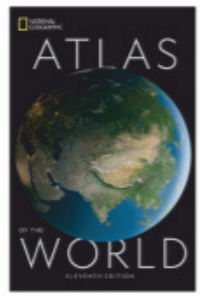

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NAT GEO WILD

Reforming the toughest canines on *Dog: Impossible*

The most aggressive, dangerous, and misunderstood canines—the ones that most trainers won't touch—are the dogs that Matt Beisner (above) takes on. Since transforming his own bad behaviors, Beisner says, he has dedicated his life to helping owners learn how to handle their dogs, as well as to rescuing and rehabilitating animals that others turn away. The six-episode series *Dog: Impossible* premieres September 8 at 10/9c on Nat Geo WILD.



BOOKS

A new *Atlas of the World* to explore

The 11th edition of this classic reflects the state of the world today with authoritative maps, data-driven graphics, and much more. It's available October 1 wherever books are sold and at *shopng.com/books*.

TELEVISION

Plunge back into *Life Below Zero*

Back for a 12th season: *Life Below Zero,* the saga of tough Alaskans living off the grid. Witness scenes of whiteout snowstorms and encounters with man-eating carnivores. The new season premieres September 24 at 9/8c on National Geographic.

NAT GEO TRAVELER

Our music issue maps out 'sound journeys'

Travels with a hip-hop artist, musical quests and curiosities, a guide to global sound scenes—and each article is paired with a Spotify playlist. There's more on *Traveler*'s sound journeys issue at *natgeotravel.com/music*.

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SPECIAL ISSUE

The State of the Arctic

BY **SUSAN GOLDBERG** PHOTOGRAPH BY **KATIE ORLINSKY**



This Inupiat youngster accompanied a hunting party that unsuccessfully sought bearded seals in the Arctic Ocean near Utqiaġvik (Barrow), Alaska. Warming weather has affected the Inupiat's hunts, the community's main source of food.

AS SOIL A COUPLE OF FEET DEEP GOES FROM FROZEN TO MUSH, THE RELEASE OF CARBON COULD PUSH CLIMATE CHANGE TO A TIPPING POINT.

IN THE SPRING of 2018, my husband and I went to the Arctic on a National Geographic expedition. We'd never been before and were struck by the scale of its rugged beauty, the white-blue glaciers glinting in the midnight sun, and the abundant wildlife. I'll never forget seeing an enormous walrus face down a young polar bear (which wisely decided to move along).

I also won't forget the ship's captain, Leif Skog, announcing that we had traveled farther north than this expedition ever had before. We knew that was saying something—Skog had been navigating polar waters for four decades. How amazing, we initially thought.

And then, of course, the experience turned sobering as we realized why we'd gotten so far: because sea ice that normally halts the ship's northward progress had melted. In this issue we look at that and other effects of climate change on the Arctic, from shifting geopolitical power to thawing permafrost.

As soil a couple of feet deep goes from frozen to mush, the release of carbon could push climate change to a tipping point, writer Craig Welch reports in "The Threat Below" in this issue. With the Arctic warming much faster than the rest of the planet, Welch writes, "In 2017 tundra in Greenland faced its worst known wildfire." Meanwhile, "Lakselv, Norway, 240 miles above the Arctic Circle, recorded a blistering 32 degrees Celsius, or 90 degrees Fahrenheit. Arctic reindeer hid in road tunnels for relief."

Like what I saw in the Arctic, what you'll read here is thought provoking. May it also be galvanizing, spurring each of us to do what we can to slow the advance of climate change. Thank you for reading *National Geographic*. ▯

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PHOTOGRAPHS BY **BARRY ROSENTHAL**

NATIONAL GEOGRAPHIC

LOOKING AT THE EARTH FROM EVERY POSSIBLE ANGLE



WHAT THE TIDE BRINGS IN

An endless supply of ocean trash provides the material for an ongoing art project.

VOL. 236 NO. 3

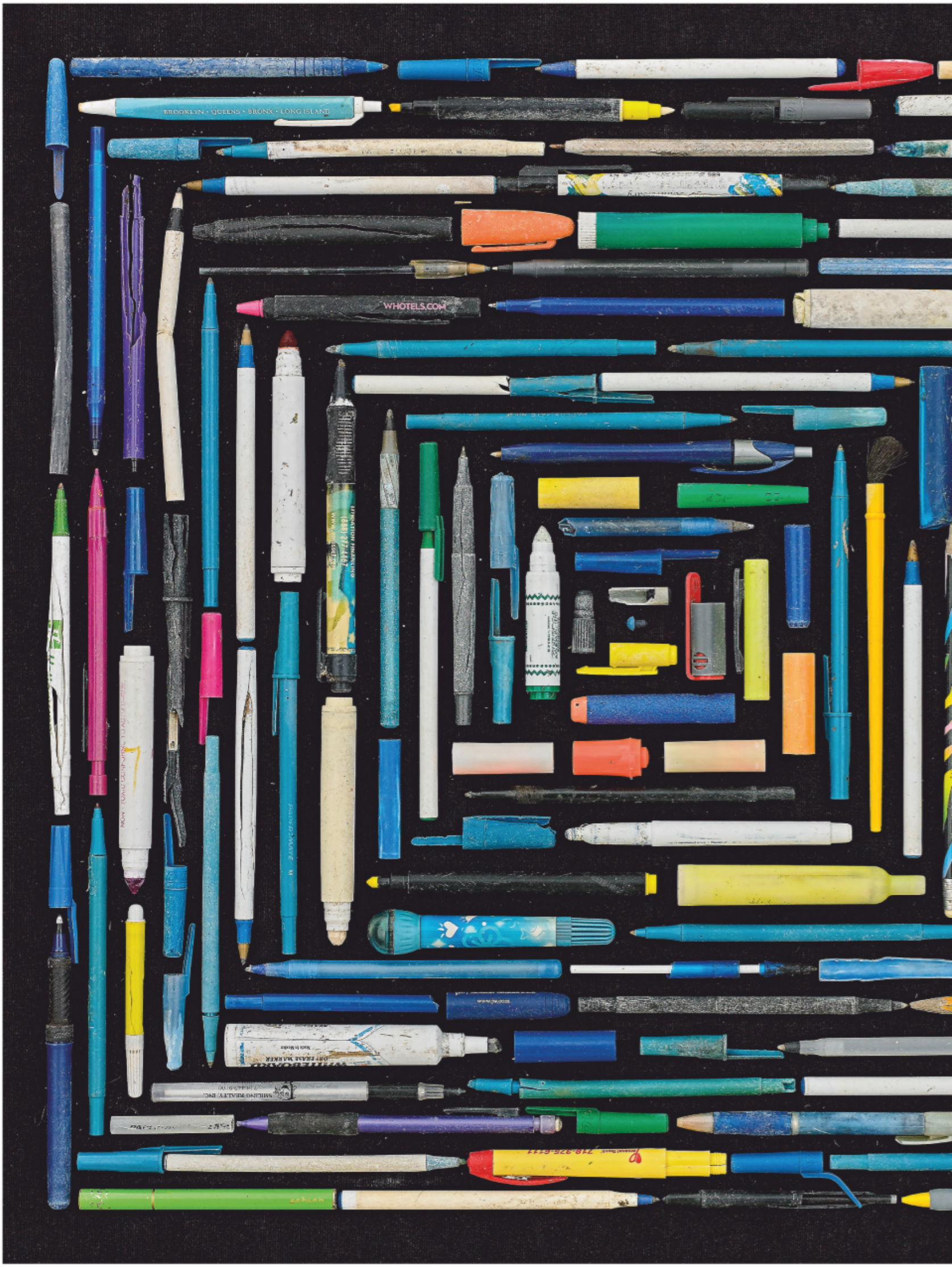




PREVIOUS PAGES: Artist Barry Rosenthal builds these assemblages to illustrate the extent of marine pollution. He keeps trash in his studio for months—sometimes years—until a critical mass of color emerges.



ABOVE: These objects have little in common beyond their shades of white—and their slow degradation by ocean waves, harsh sunlight, sand, and salt.



Rosenthal created an angular portrait out of pens, pencils, and markers. He finds the writing utensils strewn by the hundreds on a New York beach, many of them no longer usable.







Manufacturers design products such as plastic utensils and to-go cups to be used only once. But these items don't go away: Scientists believe some plastic trash lasts forever.

PLANET **OR** PLASTIC?

THE BACKSTORY

TRASH FROM A NEW YORK BEACH IS ASSEMBLED INTO VIBRANT AND SOBERING SCULPTURES.

BEACHES ACROSS THE PLANET share many characteristics: sand, water, ocean breezes—and plastic. At Floyd Bennett Field in Brooklyn, New York, the coastal area where artist Barry Rosenthal goes collecting, trash piles up fast and in layers, as if at an archaeological site.

Plastics will indeed be the artifacts of our era, particularly in oceans, where the material invades ecosystems and floats around the world. More than five trillion pieces of plastic already fill the seas, with some nine million tons added each year.

Rosenthal observed how bottles, toys, and food wrappers fade, wear out, yet never disappear. He started building and photographing sculptures of ocean trash to illustrate the problem of marine pollution. Eventually he began to gather the detritus to use as his art materials, cleaning a small section of the coast over and over again. "I started to just collect as much as I could and go back to my studio to sort it out," he says. Each sculpture has a theme, by color, shape, or intended use, such as the motor oil containers below.

A project begun for aesthetics has acquired a second purpose: raising social and environmental awareness. Now Rosenthal travels to speak about ocean pollution and what might help clean it up. The most meaningful advance, he says, would be to rethink our method of consuming.

"We need a paradigm shift in all packaging design," he says. "Not just plastic bags and straw bans to make people feel good." —DANIEL STONE



Learn more about plastic waste and take the pledge to reduce it at ***natgeo.com/plasticpledge.***

THE DISCOVERIES OF TODAY THAT WILL DEFINE THE WORLD OF TOMORROW

NATIONAL GEOGRAPHIC | VOL. 236 NO. 3

Why You Like What You Like

THINK YOU HAVE GOOD TASTE? YOU DON'T DESERVE THE CREDIT. THANK YOUR GENES, YOUR GERMS, AND YOUR ENVIRONMENT.

BY **BILL SULLIVAN**

THERE MAY BE NOTHING more self-defining than our tastes. Whether in food, wine, romantic partners, or political candidates, our tastes represent our identity. So it made sense to me that my likes and dislikes were formed through careful deliberation and rational decision-making—that is, through choices where I wielded some control.

Then I became acquainted with *Toxoplasma gondii*. In my research at the Indiana University School of Medicine, I observed how the single-celled *T. gondii* parasite can change the behavior of the host it infects. It can make rats unafraid of cats, and some studies show that it may cause personality changes (such as increased anxiety) in humans.

These studies made me wonder if there are other things happening under our radar that could be shaping who we are, programming our likes and dislikes. As I dug into the scientific literature, I hit upon this astonishing and unsettling truth: Our

SCIENCE HAS SHOWN THAT YOU ARE NOT WHO YOU THINK YOU ARE. THERE ARE BIOLOGICAL GREMLINS DRIVING EVERY ACTION AND PERSONALITY TRAIT THAT YOU ASSUMED WERE OF YOUR OWN VOLITION.

actions are governed by hidden biological forces—which is to say that we have little or no control over our personal tastes. Our behaviors and preferences are profoundly influenced by our genetic makeup, by factors in our environment that affect our genes, and by other genes forced into our systems by the innumerable microbes that dwell inside us.

I realize that this sounds ridiculous. We're taught that we can be whatever we want to be, do whatever we want to do. Intuitively, it feels like we pick and choose the foods we like, who we give our heart to, or which buttons we press in the voting booth. To suggest that we are just meat robots under the influence of unseen forces is crazy talk!

Several years ago I would have agreed. But after being grilled at one too many cookouts as to why I don't like many of the vegetables that most people find enjoyable, I felt like something was wrong with me. I am green with envy watching people willingly eat things like broccoli, because if someone tries to pass it to me, my body recoils in horror. Why don't I relish broccoli?

I wasn't choosing to hate these vegetables, so I set out to learn what could explain my aversion. Luckily, science was on the case. Researchers have found that about 25 percent of people might hate broccoli for the same reason I do. These people—my people—are called supertasters. We have variations in genes that build our taste bud receptors. One of those genes, *TAS2R38,* recognizes bitter chemicals like thioureas, which are plentiful in broccoli. My DNA gives me taste bud receptors that register thiourea compounds as revoltingly bitter. This may be DNA's way of deterring me from eating harmful plants. It's clearly the reason that, as television's *Seinfeld* character said of his frenemy Newman, I wouldn't eat broccoli if it were deep fried in chocolate sauce.

THIS EXPLANATION of why I hate broccoli is both vindicating and disturbing. I am relieved that my distaste for cruciferous vegetables is not my fault—I did not get to go gene shopping before I was conceived. But the relief soon turns to alarm as I wonder: What other things that define who I am are beyond my command? How much of me is really due to me?

How about my taste in women? Surely that must be under my control. Let's start with the basics: Why am I attracted to women instead of men? This was not a conscious decision that I made while sitting on

Are you really just a pile of genes?

Technically, yes. But embedded within your genome, there are many potential versions of you. The person you see in the mirror is just one of them, fished out by the unique things you've been exposed to since conception. The new science of epigenetics is the study of how chemical changes made to DNA, or proteins that interact with DNA, can affect gene activity. DNA can be modified by environmental factors in ways that can profoundly affect development and behavior. Recently, it's also been shown that the microbes in your body—aka your microbiome—can be a significant environmental factor that affects myriad behaviors, from overeating to depression. In sum, we are our genes—but our genes cannot be evaluated outside the context of our environment. Genes are the piano keys, but the environment plays the song. –BS





ILLUSTRATION: DAVID PLUNKERT

the beach one evening contemplating life; I was born this way. The genetic components to human sexuality are still muddy, but it is clear that it's not a choice.

Regardless of our sexual orientation, we seem to have an innate sense of the attributes we find desirable in a mate. Features such as a shapely mouth, sparkling eyes, and lush hair are widely appreciated as attractive. And studies show that more attractive people are likelier to get a job, make more money, find a mate—even be found "not guilty" if on trial.

Evolutionary psychologists remind us that at our core, virtually everything we do emerges from a subconscious urge to survive and reproduce our genes, or lend support to others (such as family) who carry genes like our own. They further postulate that many of the physical traits that we consider attractive are signs of physical health and fitness—in other words, good genes to let swim in our pool.

Science has also provided a little comfort as to why your amorous advances are sometimes spurned. A famous study had women sniffing the underarms of T-shirts worn by men and then ranking the odor. The more similar the men's and women's immune system genes were, the worse the T-shirt stank to the women. There is a sound evolutionary explanation for this: If parental immune genes are too similar, the offspring will not be as well equipped to fight pathogens. In this case, genes used odor receptors as a proxy to size up whether a potential mate's DNA is a good match. Studies like this affirm that chemistry between people really is a thing. Perhaps we should not take another's romantic disinterest personally but view it more like organ rejection.

Somewhat distressed at the level of control genes seem to exert over our choices in life, I investigated an area that I was sure would be impervious to the reach of DNA: our taste in political leaders. It's easy to imagine genes playing a role in whether someone is right- or left-handed, but whether a person leans politically to the right or left? I thought not. Yet as unlikely as it seems, the votes are in, and DNA has scored another victory.

Scientists have uncovered distinct personality traits that tend to be associated with people on opposite ends of the political spectrum. In general, liberals tend to be more open-minded, creative, and novelty seeking; conservatives tend to be more orderly and conventional, and to prefer stability. Identical twins separated at birth and raised in different environments typically find their political stances in agreement when reunited, suggesting a genetic component to our political compass. Several studies suggest that variations in our dopamine D4 receptor gene *(DRD4)* influence whether we vote red or blue. Dopamine is a key neurotransmitter in the brain, associated with our reward and pleasure center; variations in *DRD4* have been tied to novelty seeking and risktaking, behaviors more commonly associated with liberals.

Other research has shown that certain areas in the brain are different for liberals and conservatives, and this may affect how they respond to stressful stimuli. For example, conservatives tend to have a larger amygdala, the fear center of the brain, and have stronger physiological reactions to unpleasant photos or sounds. Considered together, these biological differences may partially explain why it's so difficult for a liberal or conservative to get the other to "see the light." You're asking people not just to change their mind but also to resist their biology.

THESE EXAMPLES ARE JUST the tip of the iceberg. The truth is, every human behavior—from addiction to attraction to anxiety—is tethered to a genetic anchor. This is not to say that we're destined to be slaves of our DNA, however. DNA has built human beings a brain so magnificent that it has figured out DNA's game. And with the advent of gene editing, we have become the first species capable of revising our genetic instructions.

Science has shown that you are not who you think you are. There are biological gremlins driving every action and personality trait that you assumed were of your own volition. This realization is disheartening at first, but knowledge is power. Knowing the molecular basis of our adverse behaviors should put us in a better position to curb or remedy them; accepting that other people have little choice in how they came to be should engender more empathy and compassion. Perhaps, with the confidence that we are *not* in total control, we can resist the urge to praise or blame and seek understanding instead. ▯

Bill Sullivan is a professor of pharmacology and microbiology at the Indiana University School of Medicine, where he studies infectious disease and genetics. His book *Pleased to Meet Me: Genes, Germs, and the Curious Forces That Make Us Who We Are* is available where books are sold and at *shopng.com/books*.





Death-defying DNA

HOW OZZY OSBOURNE'S GENES MAY PLAY INTO HIS HEAVY METAL LIFESTYLE

During his 50-year heavy metal music career, Ozzy Osbourne has become famous for his alcohol and drug binges. To learn what allowed Osbourne to survive cocaine for breakfast and four bottles of cognac a day for decades, scientists analyzed his DNA in 2010. They found a never before seen mutation in a gene that's involved in breaking down alcohol. They also found variations in genes linked to drug absorptions, addiction, and alcoholism—variations that would make Osbourne six times as likely as an average person to crave alcohol and 1.3 times as likely to have a cocaine addiction. **—BS**

PHOTO: TERJE DOKKEN, GONZALES PHOTO/ALAMY



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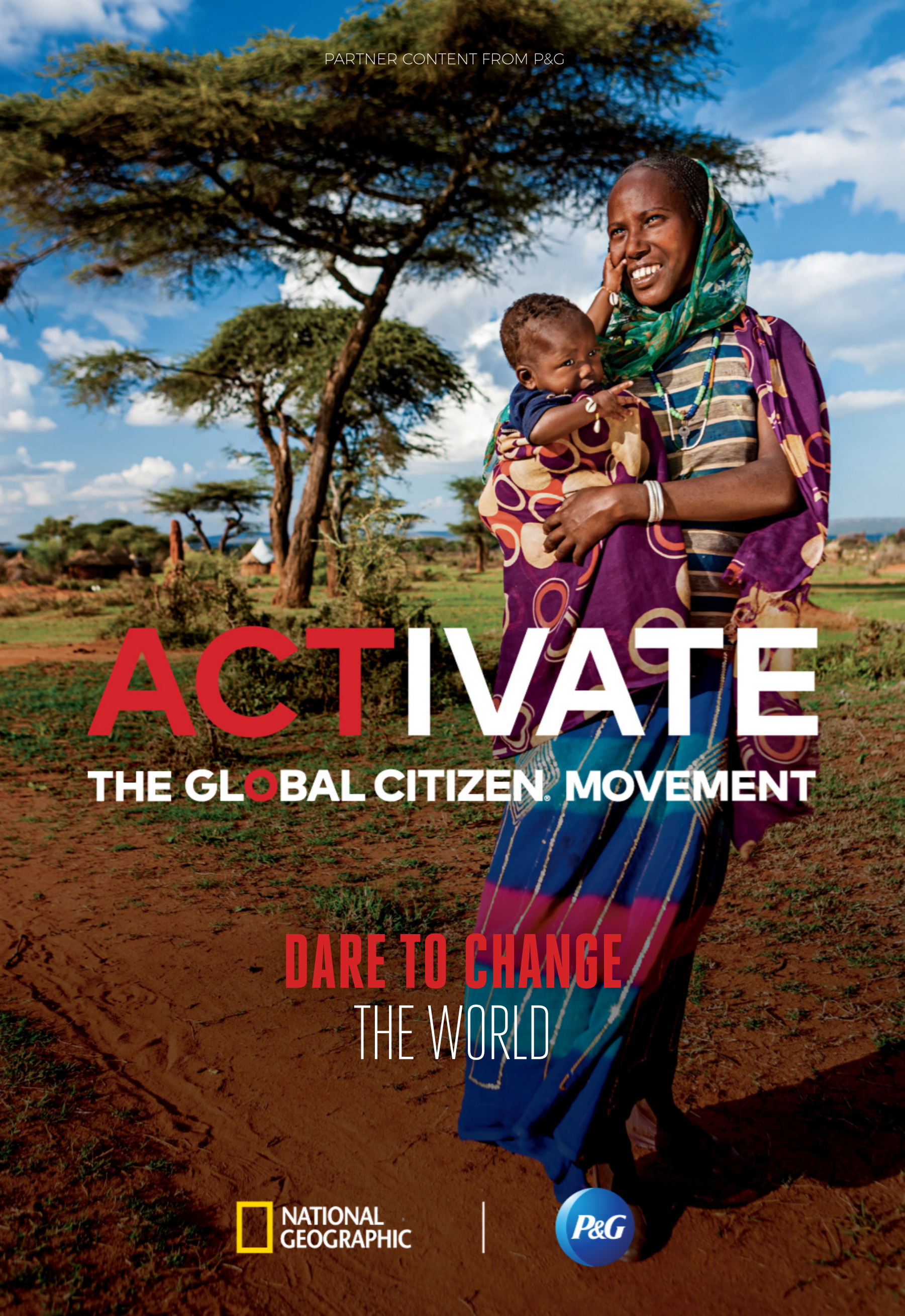


A SOLAR SYSTEM GIANT, READY FOR ITS CLOSE-UP

IMAGE BY **KEVIN GILL**

As NASA's Juno probe circles Jupiter, data from its JunoCam let citizen scientists make stunning images of the planet. Kevin Gill assembled this one, in which he sees the "huge" Great Red Spot flanked by "almost like a river of clear skies." **–MICHAEL GRESHKO**

SOURCE: NASA/JPL/SWRI/MSSS



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P&G BELIEVES IN USING THEIR VOICE IN ADVERTISING AS A FORCE FOR GOOD by addressing important societal issues while ensuring positive, accurate portrayals of all people. Their newest film, "The Look" follows a Black man in America throughout his day as he encounters a variety of "looks" that symbolize a barrier to acceptance —and differing levels of bias. Through this effort, P&G hopes to drive conversations that lead to understanding, develop empathy, and help activate change.

To learn more about how P&G is leading this conversation, visit **TalkAboutBias.com**.

SOCIAL JUSTICE REFORM

Watch the episode on September 12, 2019

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DISASTER RELIEF AID

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Watch the episode on September 26, 2019

To learn more, visit
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REDUCING THE AMOUNT OF PLASTIC we use and investing in better ways to collect and recycle it can go a long way to keep plastic out of the oceans.

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P&G, MAKERS OF TIDE, INTRODUCED ITS *CHILDREN'S SAFE DRINKING WATER* PROGRAM IN 2004 and since then, with the help of over 150 partners around the world, has provided more than 15 billion liters of clean water to people in need. The program provides an easy-to-use water purification packet invented by laundry scientists that can clean 10 liters of water in just 30 minutes and has a goal to deliver 25 billion liters of clean water by 2025.

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NATIONAL GEOGRAPHIC

DISPATCHES
FROM THE FRONT LINES
OF SCIENCE
AND INNOVATION

Hip-hop makes cheese funky
Swiss researchers exposed wheels of Emmentaler to different genres of music. Six months later they did a taste test. The wheel with the strongest aroma and flavor was the one that had "listened" to A Tribe Called Quest. A jury of culinary experts confirmed the investigators' conclusions.





CULTURE

Why Warriors Wielded Human Bones

New Guinean men once warred with daggers made from cassowary—or human—bones. Anthropologist Nathaniel Dominy tested the strength of both types of weapon. He likens the bird-bone dagger (left) to a Timex watch: "It works just as well, but if it breaks, then it is easy to replace." Daggers crafted from human femurs "are a bit like a Rolex watch—a prestige object and status symbol that one would rather not damage."—JB

ANIMALS

TECHNICOLOR SQUIRRELS

NATIVE TO TROPICAL INDIA, THESE SQUIRRELS FAR OUTDO OTHERS IN SIZE—AND HUE

IN A SOUTHERN INDIAN FOREST, an amateur photographer spied a multicolored rodent. The pictures he took set the internet alight last April, and no wonder: Indian giant squirrels can weigh four pounds and stretch three feet from tail to snout—half again (at least) the size of most European and North American squirrels. Unlike those northern nibblers, these behemoths forage in the tropical canopy, where their flexible feet and ankles allow them to leap 20 feet from branch to branch.

The vibrant fur may provide camouflage "in the mosaic of shade and sun flecks where these arboreal giants thrive," says John Koprowski, author of *Squirrels of the World*. Or, says evolutionary biologist Dana Krempels, "there could be an evolutionary 'tightrope' that the squirrels must walk"—bright enough for other giant squirrels to spot, but not so bright that predators notice. —JEREMY BERLIN



PHOTOS (FROM TOP): STEFAN WERMUTH, UNIVERSITY OF THE ARTS BERN; HOOD MUSEUM OF ART, DARTMOUTH: HARRY A. FRANKLIN FAMILY COLLECTION, PHOTOS BY JEFFREY NINTZEL; HEMIS/ALAMY STOCK PHOTO

TWEETS OF MANY TONGUES

BY **MONICA SERRANO**

How integration is measured

Groups were identified by the languages used in tweets; Twitter users' neighborhoods were identified based on where they most often stay overnight (8 p.m. to 8 a.m.).





London is marked by high integration among the largest range of languages identified on Twitter (24).

EN — Each square represents a language or language group, in this case English. The top square is the most integrated.



Berlin—among the world's more integrated cities—has the fewest foreign language groups tracked in the study.

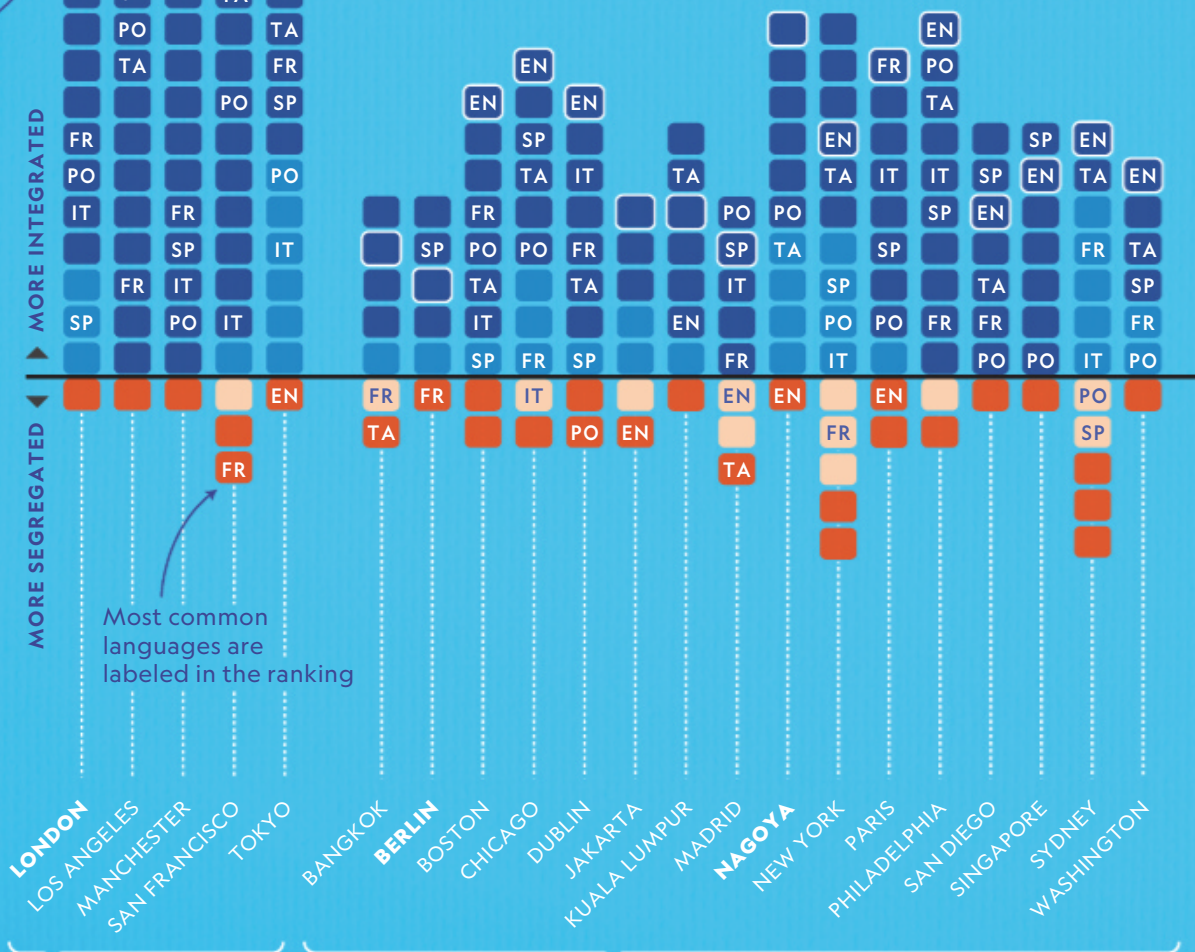


Nagoya, Japan, has 10 non-native language groups; members of five of them are well integrated across the city.

London, for example...

has 20 **highly integrated languages or language groups (■),** meaning they're as spread out as London's English speakers are. Three communities are **moderately integrated (■),** while none are **moderately segregated (■).** The city does have one language group—here, they're Arabic speakers—who tend to live in specific, distinct neighborhoods and are thus considered **highly segregated (■).**

□ Native language



Highly integrated

London and a handful of global cities have linguistically diverse populations and few self-segregated ethnic neighborhoods.

Moderately integrated

About one-third of the analyzed cities are linguistically diverse and have relatively high rates of integration.

(*) FRENCH SPEAKERS IN MONTRÉAL ALSO SPEAK ENGLISH.

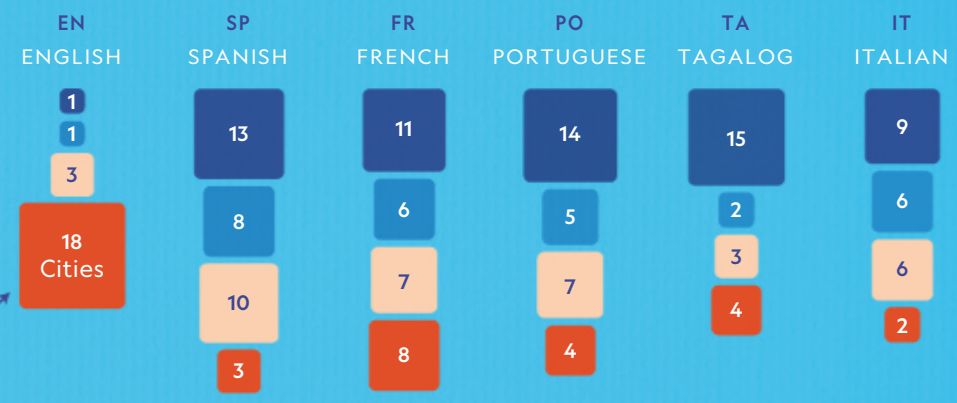
CITIES WITH RESIDENTS TWEETING IN FEWER THAN THREE LANGUAGES ARE NOT SHOWN.

THE WORLD'S CITIES HAVE ALWAYS BEEN MELTING POTS for immigrants. Do newcomers congregate in ethnic enclaves such as San Francisco's Chinatown? Or do they scatter, getting fully absorbed into their new homes? To track integration, researchers took Twitter data from some 50 cities worldwide to identify language groups and their residential neighborhoods; findings were then compared with those of the city's native-language speakers. By reading the Twitter patterns, researchers concluded that diverse and well-integrated immigrant communities like those in London exist in less than half the cities studied. In the rest, the data show varying degrees of self-segregation, with immigrants who share the same language sticking together in the same part of the city.

HOW THE MOST COMMON LANGUAGES INTEGRATE

Speakers of the six most common languages in the Twitter study display a range of integration across major world cities whose native languages differ from their own.

English speakers, for example, are highly segregated in 18 of the 50 cities shown.





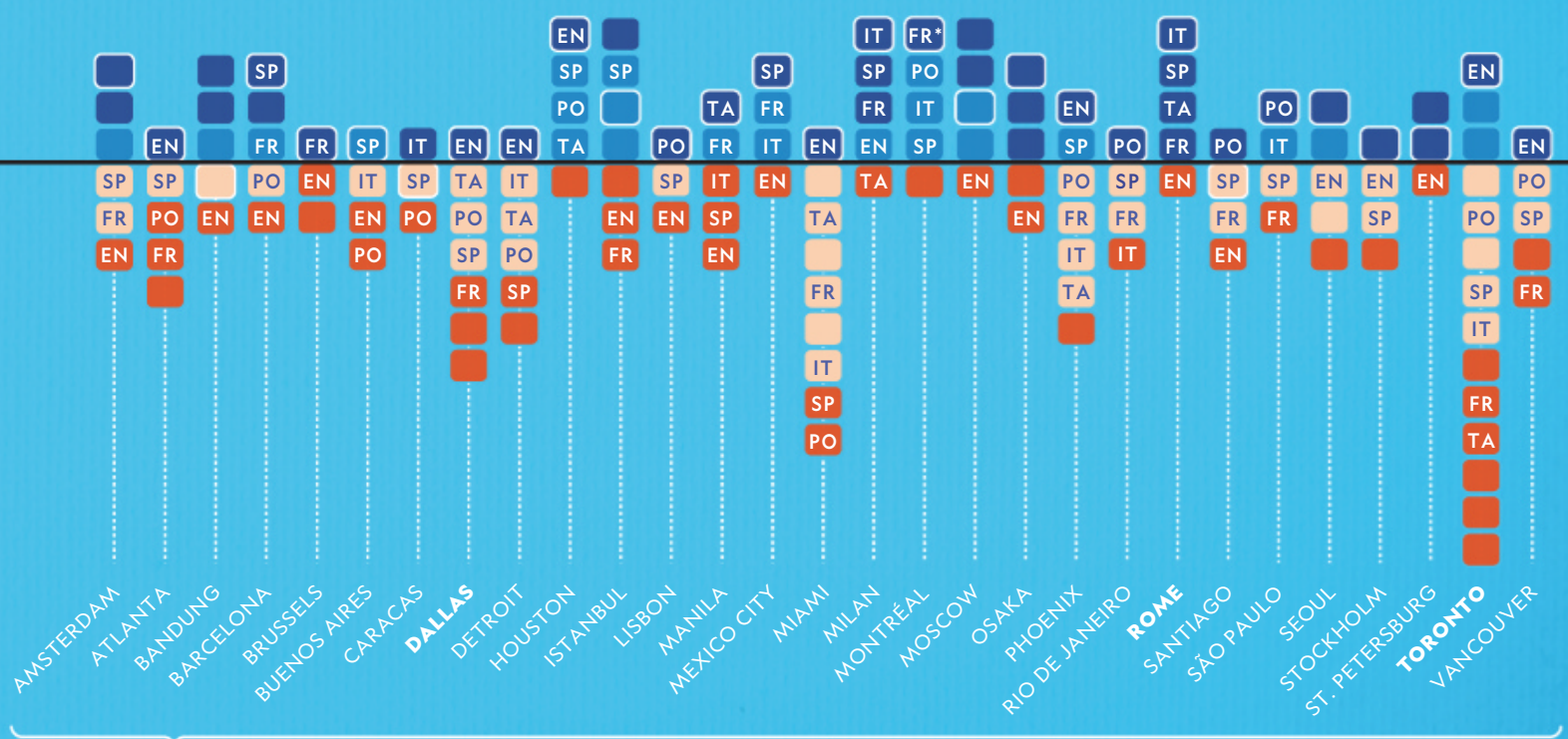
In **Dallas** speakers of Tagalog (a Philippine language) form one of its smallest but most integrated immigrant communities.



Wealthier immigrant groups, such as English speakers in **Rome,** can self-segregate in specific areas.



Toronto is marked by the highest degree of self-segregation, despite being among the study's most linguistically diverse cities.



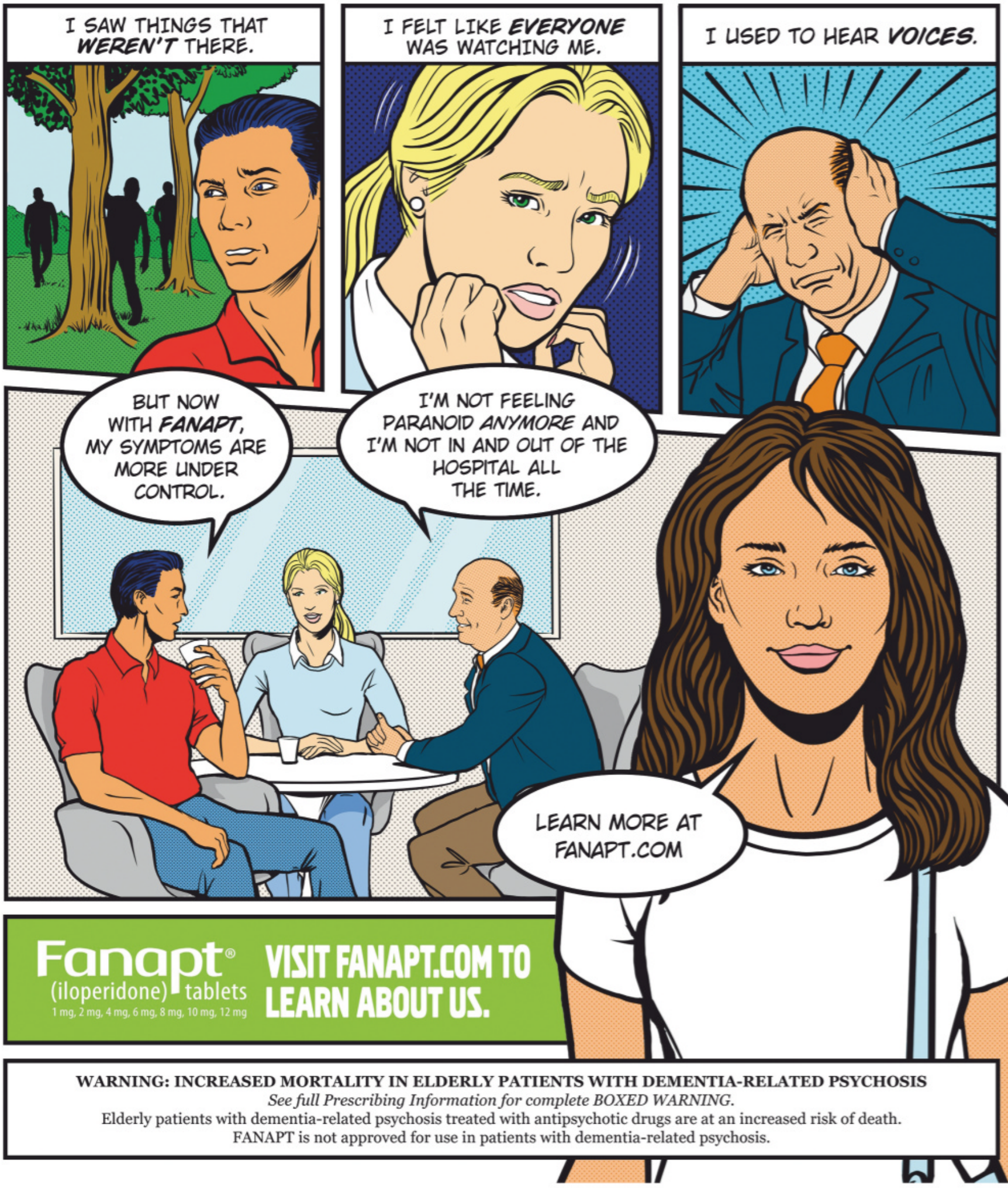
Less integrated

In more than half the cities studied, there are only a few language groups and higher numbers of self-segregated ethnic neighborhoods.

TWITTER TRAFFIC DOES NOT CAPTURE POTENTIALLY LARGE GROUPS OF IMMIGRANTS WHO FAVOR OTHER SOCIAL MEDIA PLATFORMS.

SEAN MCNAUGHTON. SOURCE: FABIO LAMANNA AND OTHERS, "IMMIGRANT COMMUNITY INTEGRATION IN WORLD CITIES," *PLOS ONE*, 2018

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WARNING: INCREASED MORTALITY IN ELDERLY PATIENTS WITH DEMENTIA-RELATED PSYCHOSIS

See full Prescribing Information for complete BOXED WARNING.

Elderly patients with dementia-related psychosis treated with antipsychotic drugs are at an increased risk of death.

FANAPT is not approved for use in patients with dementia-related psychosis.

Important facts about FANAPT® (iloperidone) tablets

PURPOSE

Fanapt® is a prescription medication used for the treatment of schizophrenia in adults.

Deciding to look at alternate medications is something your health care provider may do. Your health care provider needs to consider that Fanapt® may change your heart rhythm (meaning there is more time between heartbeats). When taking other drugs that may cause this same change in heart rhythm, you are at a higher risk of a serious, even life-threatening medical issue (torsade de pointes), which may result in sudden death. In many cases, your health care provider may prescribe another medication like Fanapt® first.

Fanapt® needs to be taken as directed starting at a low dose and slowly increasing the strength. This may delay the control of symptoms in the first 1 to 2 weeks of treatment.

IMPORTANT SAFETY INFORMATION BOXED WARNING:

Elderly patients with psychosis related to dementia (having lost touch with reality due to memory loss and experiencing a decline in day-to-day functioning) who are treated with antipsychotic medications are at an increased risk of death compared to patients treated with a placebo. Fanapt® is not approved for use in people with dementia-related psychosis.

Patients should not use Fanapt® if they have a known allergy to Fanapt® or its ingredients. Allergic reactions, including anaphylaxis, rapid swelling of the skin (angioedema), and other symptoms of allergy (e.g., throat tightness; swelling of the throat, face, lips, mouth and tongue; hives; rash; and itching) have been reported.

An increased risk of stroke has been reported in clinical studies of elderly people with dementia-related psychosis. Fanapt® is not approved for use in people with dementia-related psychosis.

Fanapt® may change your heart rhythm (meaning there is more time between heartbeats). Heart rhythm changes have occurred in patients taking Fanapt® and are a risk factor for serious, even life-threatening medical issues. You should tell your health care provider if you have or have had heart problems. Contact your health care provider right away if you feel faint or have unpleasant feelings of irregular or forceful heartbeats as any of these feelings could be a sign of a rare, but serious side effect that could be fatal. You should not use Fanapt® with other drugs that are known to cause these same heart rhythm issues.

Tell your health care provider if you have some or all of the following symptoms: very high fever, rigid muscles, shaking, confusion, sweating or increased heart rate and blood pressure. These may be signs of a condition called neuroleptic malignant syndrome (NMS), a rare but serious side effect that could be fatal. This may happen with Fanapt® or drugs like it.

Abnormal or uncontrollable movements of the face, tongue, or other parts of the body may be signs of a serious condition called tardive dyskinesia (TD), which could become permanent.

The chance of this condition going away decreases, depending on how long and how much medication has been taken. Tell your health care provider if you have body movements you can't control.

Fanapt® and medicines like it have been associated with metabolic changes (high blood sugar, high cholesterol and triglycerides, and weight gain) that can increase cardiovascular/cerebrovascular risks.

Tell your health care provider if you have diabetes or risk factors for diabetes (for example, obesity, family history of diabetes), or if you have unexpected increases in thirst, urination, or hunger. If so, your blood sugar should be monitored. Increases in blood sugar levels (hyperglycemia), which in some cases can be serious and associated with coma or death, have been reported in patients taking Fanapt® and medicines like it.

Changes in cholesterol and triglycerides have been seen in patients taking Fanapt® and medicines like it. Check with your health care provider while on treatment.

Some patients may gain weight while taking Fanapt.® Your health care provider should check your weight regularly.

Tell your health care provider about any medical conditions that you have including problems with your liver. Fanapt® is not recommended for patients with severe liver problems.

Tell your health care provider if you have a history of or have a condition that may increase your risk for seizures before you begin taking Fanapt.®

Light-headedness or faintness caused by a sudden change in heart rate and blood pressure when rising quickly from a sitting or lying position (orthostatic hypotension) has been reported with Fanapt.® This condition is most common when you start therapy, when restarting treatment, or when the dose of Fanapt® is increased. You should consult your health care provider if you have or have had heart problems or conditions that lead to these sudden changes since Fanapt® should be used with caution in these patients.

Fanapt® may increase the risk of falls, which could cause fractures or other injuries.

Decreases in infection-fighting white blood cells (WBCs) have been reported in some patients taking antipsychotic agents. Patients with a preexisting history of low WBC count or who have experienced a low WBC count due to drug therapy should have their blood tested and monitored during the first few months of therapy. Some (including fatal) cases of agranulocytosis, a serious decrease in specific types of WBCs called neutrophils or granulocytes, have been reported in drugs like Fanapt.®

Fanapt® can increase the level of the hormone prolactin. Tell your health care provider if you experience breast enlargement, breast pain, or breast discharge, abnormal menstrual cycles in females or impotence in males. If elevated levels of prolactin persist, this may lead to bone loss.

Medicines like Fanapt® can impact your body's ability to reduce your body temperature. You should avoid overheating and dehydration.

Fanapt® and medicines like it have been associated with swallowing problems (dysphagia). If you have or have had swallowing problems, you should tell your health care provider.

As with many conditions that affect the way you think or feel, thoughts of suicide may occur. If you get these feelings, seek help immediately from your health care provider, or local emergency room.

For males, in the rare event you have a painful or prolonged erection (priapism), lasting 4 or more hours, stop using Fanapt® and seek immediate medical attention.

Fanapt® and medicines like it can affect your judgment, thinking, or motor skills. You should not drive or operate hazardous machinery, including automobiles, until you know how Fanapt® affects you.

The most common side effects for Fanapt® versus placebo were dizziness, dry mouth, feeling unusually tired or sleepy, stuffy nose, feeling faint/light-headed when standing quickly, racing heartbeat, and weight gain. The average weight gain in clinical studies lasting 4 to 6 weeks was 5 pounds. If you experience any of these symptoms, talk with your health care provider.

When taking Fanapt,® you should avoid drinking alcohol, and you should not breastfeed. You should notify your health care provider if you become pregnant or intend to become pregnant while taking Fanapt.® Tell your health care provider about all prescription and nonprescription medicines, and supplements you are taking. Some medications may interact with Fanapt.®

To access the full Prescribing Information, including BOXED WARNING, visit www.Fanapt.com.

You are encouraged to report negative side effects of prescription drugs to the FDA. Visit www.fda.gov/medwatch or call 1-800-FDA-1088.

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GENIUS

ERIC BREITUNG

BY **JEREMY BERLIN** PHOTOGRAPH BY **DAN WINTERS**



Eric Breitung is a scientist at the Metropolitan Museum of Art.

TOOLS HE USES: GAS CHROMATOGRAPHY, MASS SPECTROMETRY, ION CHROMATOGRAPHY, ULTRAVIOLET-VISIBLE SPECTROSCOPY

'Preventive conservation' of art through chemistry

Eric Breitung works at the intersection of art and science—literally. A conservation scientist at New York's Metropolitan Museum of Art, he uses analytical chemistry to help preserve priceless artwork. But where others concentrate on specific paintings or sculptures, Breitung—a lifelong art lover and former General Electric research scientist—takes a broad approach: "My focus is the environment of the whole museum."

That means preparing the Met for some 60 exhibitions each year, in spaces that range from 100 to 20,000 square feet. Design elements for each exhibit contain chemicals that could be damaging, depending on the art. For instance, acetic acid in a fabric display-case liner might be safe for a clothing exhibit but would corrode metallic art. Breitung and his three-member team are trying to develop a first ever "Rosetta stone of volatile chemicals that are in modern materials, so we can determine what levels are problematic for different types of art."

Breitung's lab is at the forefront of preventive conservation in the museum world. "Conservation started by looking at how to treat objects that have been damaged…Now we're thinking about how to set up displays and storage so that kind of damage doesn't happen in the first place."

The concept isn't new, says Breitung. But the focus is. "We're sharing everything we're learning on the web in hopes that others will apply the same principles to their cultural heritage." That goes for anyone with art, whether it's in a museum or a home. □

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NATIONAL GEOGRAPHIC | VOL. 236 NO. 3

TINY SOURCES OF BIG TASTES

The microscopic parts that give herbs and spices their flavors are often the plants' defenses.

BY **ROB DUNN**
IMAGES BY
MARTIN OEGGERLI

IN HOPES OF SEEING why a peppercorn tastes peppery, Antonie van Leeuwenhoek (1632-1723) soaked one in water and put it under a microscope. The Dutch scientist imagined that its taste came from tiny spikes or darts. Instead, he saw tiny ridged spheres—and tiny moving organisms, the first bacteria ever observed.

Van Leeuwenhoek, aka the father of microbiology, glimpsed a world in the 17th century that photographer-scientist Martin Oeggerli explores today in far greater detail. Oeggerli made images of herbs and spices with a scanning electron microscope, then enhanced the plants' parts with color. Some of the parts are both factories and silos, containing chemicals that we taste and smell when we use these herbs.

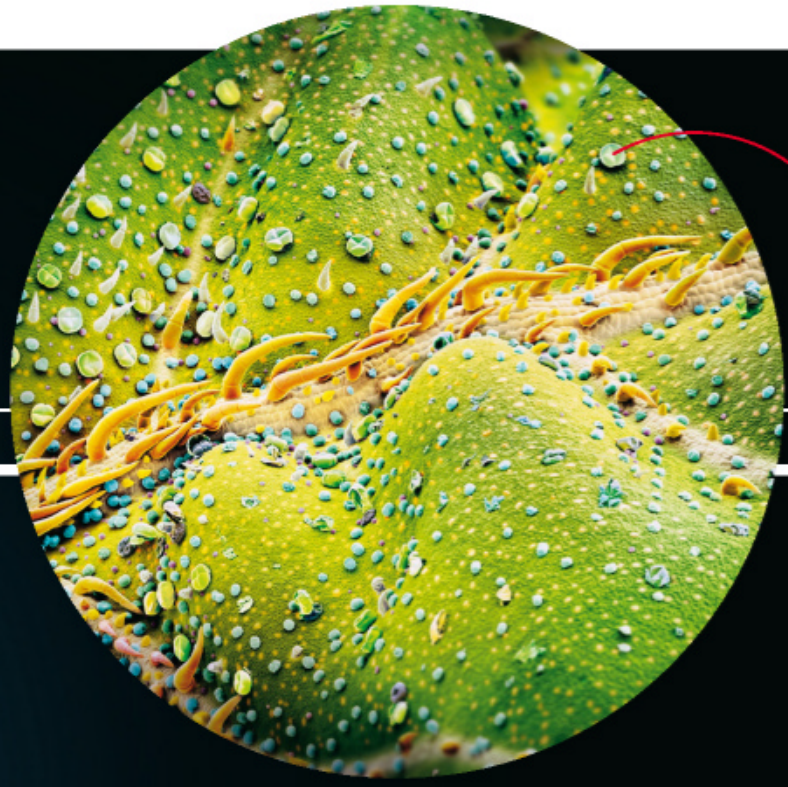
The flavors of herbs are their arsenal. Since prehistoric times, the chemicals of an herb have evolved in response to the threats that the plant must contend with. Some plants are better defended against slugs, others against sheep. In van Leeuwenhoek's peppercorn, the heat of compounds called piperines discourages insects from eating the plant. In many herbs, we find hints of the species against which the herb protected itself; in others, we still find mysteries.



SAFFRON
CROCUS SATIVUS

Some 150 compounds in the *Crocus sativus* flower's stigma give saffron its pungent taste and haylike fragrance. These compounds, including safranal, likely evolved to attract pollinators.

THESE IMAGES WERE MADE WITH A SCANNING ELECTRON MICROSCOPE, WHICH USES BEAMS OF ELECTRONS TO TRACE THE SURFACES OF OBJECTS. THE RESULT: MAGNIFIED, BLACK-AND-WHITE IMAGES THAT OEGGERLI ENHANCES WITH COLOR.

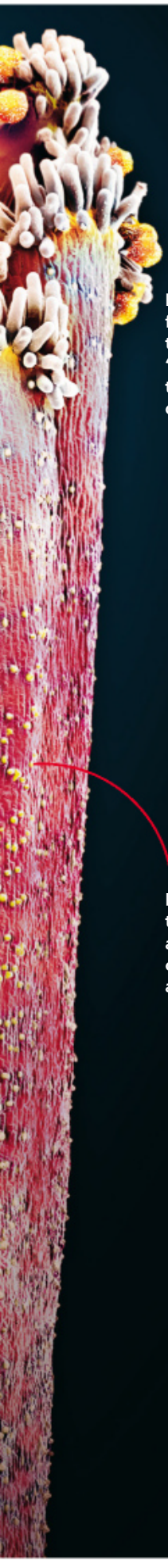


The small round structures are glands containing the chemicals that make basil's flavors and aromas.

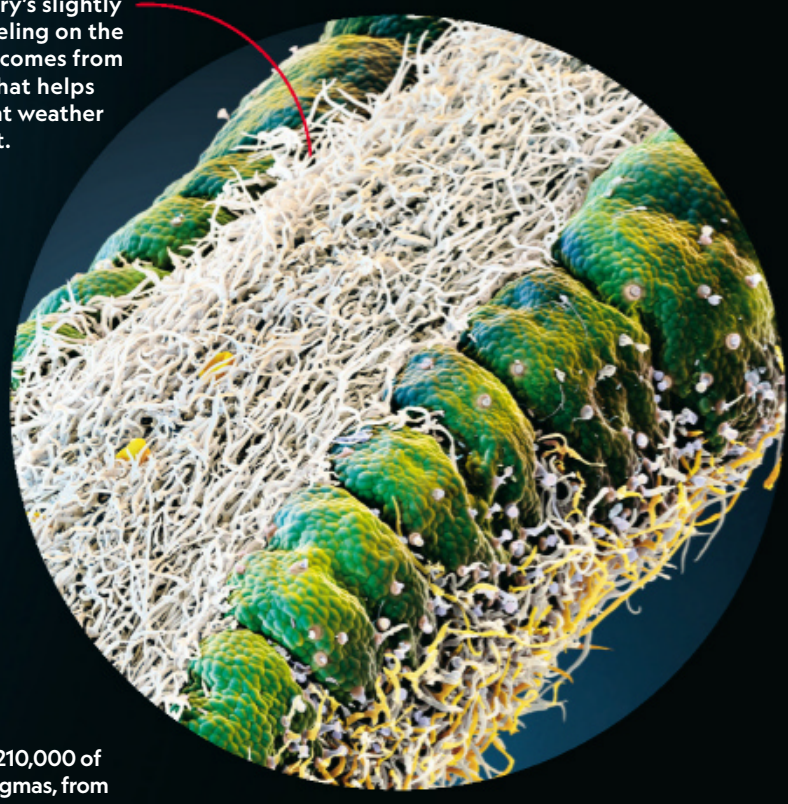
BASIL

OCIMUM BASILICUM

Each basil variety has a unique set of chemical aromas that impart flavor. Native to wetter areas, basils don't need "hairy" heat and drought shields like the herbs below do, so leaves are almost bald.



It takes 210,000 of these stigmas, from a football field's worth of crocuses, to yield a pound of saffron.

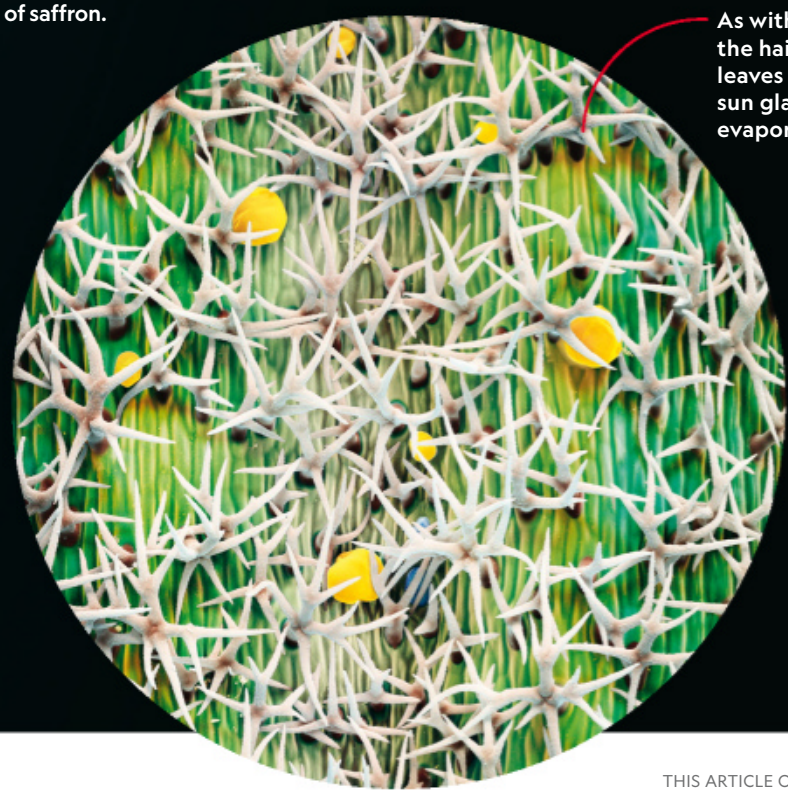


Rosemary's slightly furry feeling on the tongue comes from "hair" that helps the plant weather drought.

ROSEMARY

ROSMARINUS OFFICINALIS

Rosemary's piney flavor comes from chemicals made and stored in two structures: balloons (here, colored yellow) and tiny toadstools (here, purple and white).



As with rosemary, the hairs on lavender leaves protect from sun glare and slow the evaporation of water.

LAVENDER

***LAVANDULA* SPP.**

Scattered among spiny hairs on lavender's leaves, tiny balloons (yellow here) hold compounds that generate aroma as well as the flavor that lavender adds to foods and beverages.

THIS ARTICLE ORIGINATED IN THE SPONSORED FUTURE OF FOOD DIGITAL SERIES.

SHY BY NATURE, BUT SHOWY IN CONQUEST

PHOTOGRAPH BY **MUNMUN DHALARIA**



THE WESTERN TRAGOPAN is a scarce, shy, and elusive bird. Males are as beautiful to behold as they are rare to spot. Locals call the species *jujurana,* king of birds. Perhaps 3,300 survive in the wild, in India's Himachal Pradesh state.

That's where filmmaker Munmun Dhalaria spent most of 2017 and 2018, making a documentary on the jujurana. One day as she hid in a bird blind, a male drew near, splendid in his orange-feather ascot and white-spotted black cloak. After browsing for food, he hopped onto a boulder and began calling, aiming to woo females and warn off rivals. Dhalaria, a National Geographic explorer, watched and filmed the bird for 35 minutes, one of the longest documented jujurana sightings in the wild.

Witnessing a mating call is one thing—an actual mating, quite another. It's sometimes glimpsed at the world's only captive-breeding program for this pheasant cousin, in Himachal Pradesh. The male sidles up to the female. He deploys his finery: His head sprouts blue horns, his tail feathers fan, his rainbow wattle unfurls. At passion's peak, he ducks out of view, bursts forth again, rushes the female, mounts—and they mate for 10 seconds. Though brief, it's effective. During the next six to eight weeks, she'll lay three to five eggs and hatch them. Captive-bred birds form a reserve as wild populations shrink. The program has about three dozen birds and aims to release some into the wild in 2020. —PATRICIA EDMONDS

HABITAT/RANGE

Endemic to the western Himalaya in northern India, the bird prefers undisturbed forests with lots of undergrowth where it can feed and hide.

CONSERVATION STATUS

The International Union for Conservation of Nature labels the bird vulnerable; it is hunted for its meat and plumage, and its habitat is fragmented.

If you purchased certain Welspun home textiles labeled as "Egyptian Cotton" or "Pima Cotton," a class action Settlement may affect you.

Para ver este aviso en español, visita www.EgyptianPimaCottonSettlement.com

A proposed class action Settlement has been reached in *Hansen-Mitchell, et al. v. Welspun USA, Inc., et al*., Case No. 19-L-0391, alleging that home textile products were improperly labeled and/or marketed as "Egyptian Cotton" or "Pima Cotton." As part of the Settlement, Defendants have agreed to implement marketing reforms and provide a monetary Benefit for customers. Defendants deny any wrongdoing.

Who is a Settlement Class Member?
You may be an eligible Settlement Class Member if you purchased certain products, a description of which can be found on the website below ("Products"), between January 1, 2012 and July 2, 2019.

What are the Benefits?
Welspun has agreed to make $36,000,000 available to pay Valid Claims. Eligible Class Members with proof of purchase may receive up to $2.30 per Product for towels and pillowcases and up to $9.20 per Product for all other products purchased during the Class Period, with no Household limit; or Class Members without proof of purchase may receive up to $1.15 per Product for towels and pillowcases and up to a maximum of $4.60 per Product for all other products purchased during the Class Period, with a $10.35 Household limit. If you received a Refund for a Product, you can receive a 10% one-time discount voucher or a $5.00 credit on a future purchase if you timely submit a valid claim with your valid postal or email address. This voucher may not be clubbed or exchanged for cash. The Settlement also requires Welspun to follow certain practices when labeling products "Egyptian Cotton" and "Pima Cotton."

What are my rights?
You must file a Claim, either online at the website below or by mail, by November 27, 2019 to get a payment. You can Opt-Out and keep your right to sue Defendants about the claims released by this Settlement but you will not get a payment from this Settlement. You can Object to any aspect of the Settlement in writing by following the instructions found on the Settlement website. If you do nothing, you will not get a payment but you will be bound by all decisions of the Court. Any Opt-Out or Objection must be postmarked by September 26, 2019.

The Court will hold a Fairness Hearing in the Circuit Court for the 20th Judicial Circuit, Court of St. Clair, State of Illinois, St. Clair County Building, 10 Public Square, Belleville, Illinois 62220, before the Honorable Judge Christopher T. Kolker in Courtroom 401, 4th Floor, on October 28, 2019 at 9:00 a.m. to decide whether to approve the Settlement and to award Attorneys' Fees and Expenses of up to $9,000,000 (or the equivalent of 25% of the value of the Settlement Amount) and Administration Expenses to be paid by Defendants, plus $750 per named Plaintiff as Class Service Awards. The application for Attorneys' Fees and Expenses will be posted on the website below after being filed. You may attend this hearing, but you do not have to.

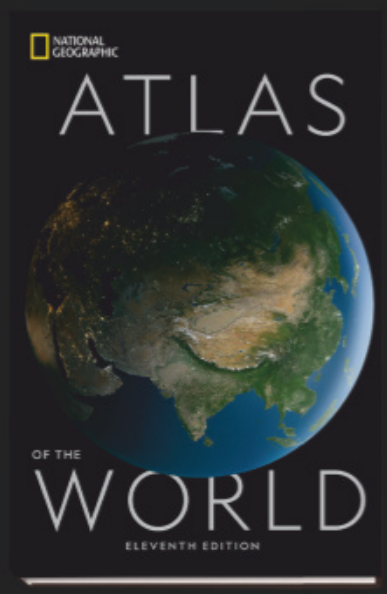
This is only a summary. Please visit *www.EgyptianPimaCottonSettlement.com*, or contact the Settlement Administrator at 1-844-271-4781 or by writing to: Mitchell v. Welspun USA, c/o Settlement Administrator, P.O. Box 58727, Philadelphia, PA 19102-8727.

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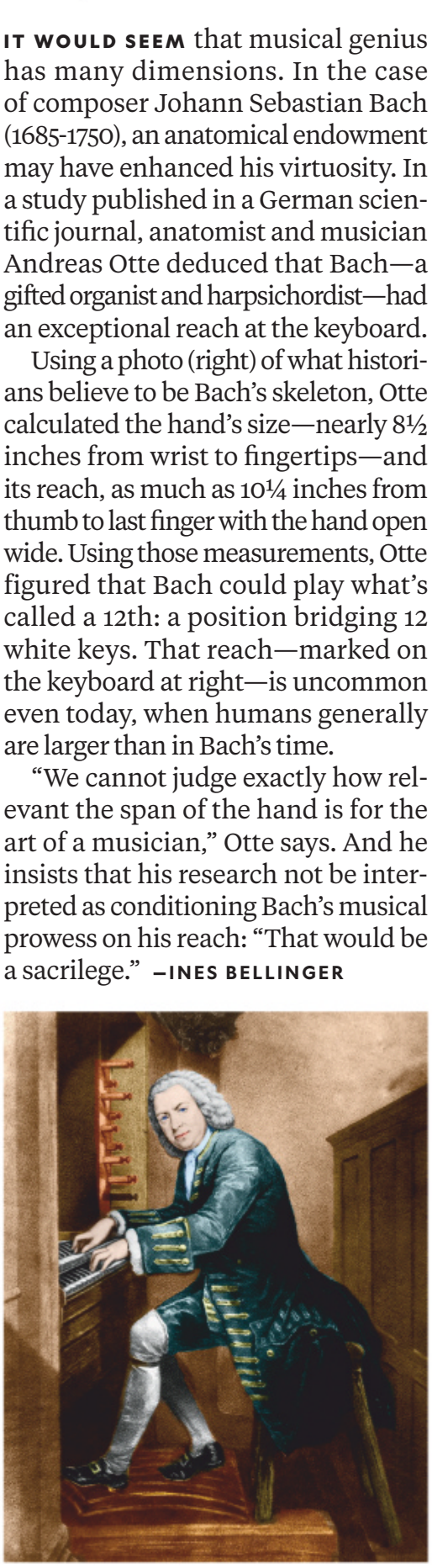

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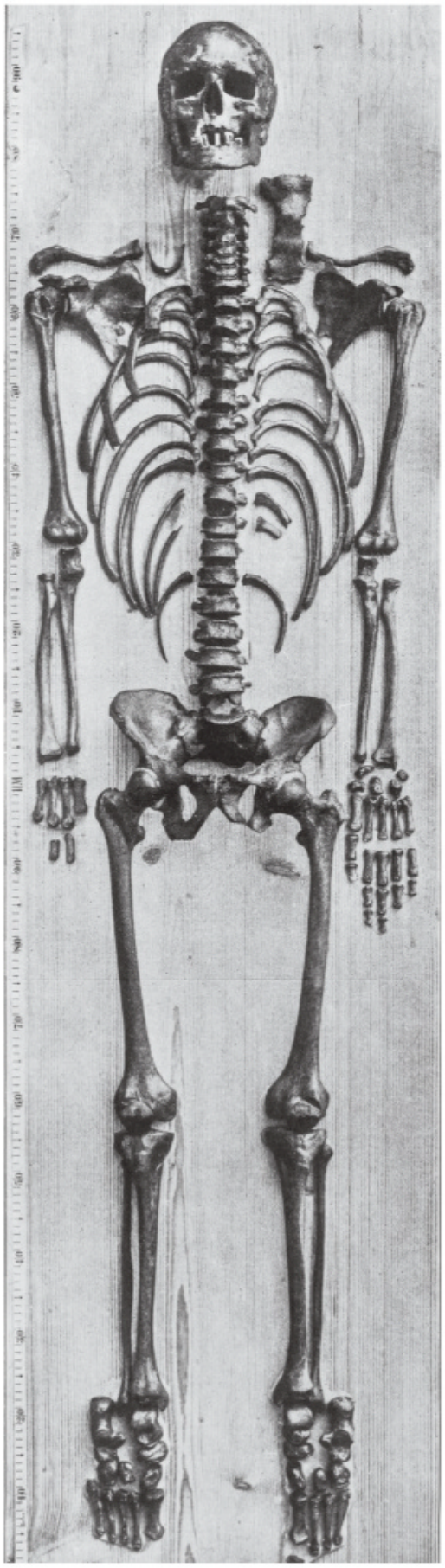
THE MUSICAL GREATNESS OF BACH'S HANDS

IT WOULD SEEM that musical genius has many dimensions. In the case of composer Johann Sebastian Bach (1685-1750), an anatomical endowment may have enhanced his virtuosity. In a study published in a German scientific journal, anatomist and musician Andreas Otte deduced that Bach—a gifted organist and harpsichordist—had an exceptional reach at the keyboard.

Using a photo (right) of what historians believe to be Bach's skeleton, Otte calculated the hand's size—nearly 8½ inches from wrist to fingertips—and its reach, as much as 10¼ inches from thumb to last finger with the hand open wide. Using those measurements, Otte figured that Bach could play what's called a 12th: a position bridging 12 white keys. That reach—marked on the keyboard at right—is uncommon even today, when humans generally are larger than in Bach's time.

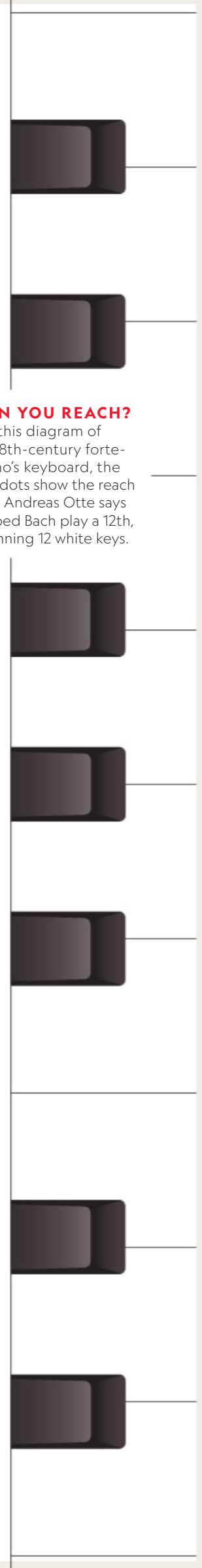
"We cannot judge exactly how relevant the span of the hand is for the art of a musician," Otte says. And he insists that his research not be interpreted as conditioning Bach's musical prowess on his reach: "That would be a sacrilege." **—INES BELLINGER**





LEFT
Baroque composer Johann Sebastian Bach's fans included scientist Albert Einstein, who's quoted as saying, "I have this to say about Bach's works: Listen, play, love, revere—and keep your trap shut."

ABOVE
What's believed to be Bach's skeleton, photographed in 1895 by anatomist Wilhelm His. Otte examined the left hand, as too many bones are missing from the right hand.



CAN YOU REACH?
On this diagram of an 18th-century forte-piano's keyboard, the red dots show the reach that Andreas Otte says helped Bach play a 12th, spanning 12 white keys.

SOURCE: MARKUS ZEPF, BACH-ARCHIV LEIPZIG (PIANO KEYS). PHOTOS: FINE ART IMAGES/HERITAGE IMAGES/GETTY IMAGES; SAXON STATE AND UNIVERSITY LIBRARY DRESDEN (SKELETON)

TIGERS FROM A DIFFERENT ANGLE

PHOTOGRAPH BY **MARK THIESSEN**

EVERY PHOTOGRAPHER has a dream shot. For Steve Winter, that shot was a tiger's face seen from below. The challenge, says Winter—who has long covered big cats and other wildlife for *National Geographic*—was getting that perspective in a way that didn't end with his own face inside the animal's mouth.

Enter this apparatus, a camera mounted on a four-wheel, remote-controlled vehicle. The "camera car" had been built by National Geographic engineers but never used. Winter saw its potential to capture that looking-upward view and asked if he could take it to India for a project on tiger conservation.

In the field, the contraption didn't last long. Though male tigers "ran away" from it, Winter says, a curious female batted it with her enormous paw. That probably did the camera in—but not before it caught the shot Winter was after. **—CATHERINE ZUCKERMAN**

IN ACTION



In Bandhavgarh National Park in Madhya Pradesh, India, male tigers ran from the camera car, but this one paused long enough to be photographed.



If this female Bengal tiger wasn't spooked by the car, she didn't seem to relish its presence either. She dealt it a few blows with her paw.

Before he decided to steer the camera away, Steve Winter got the portrait and perspective he wanted in this frame of the same female.



Steve Winter took this custom-made camera car on assignment to document tigers in a new way.

PHOTOS (TIGERS): STEVE WINTER

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Death Comes for a Crocodile

BY **TREVOR BECK FROST**

A PHOTOGRAPHER CHRONICLES AN EPIC HUNT FOR A SALTWATER CROCODILE—A HUNT THAT'S A SMALL BUT CRUCIAL PART OF AN ONGOING PLAN TO SAVE THE SPECIES.

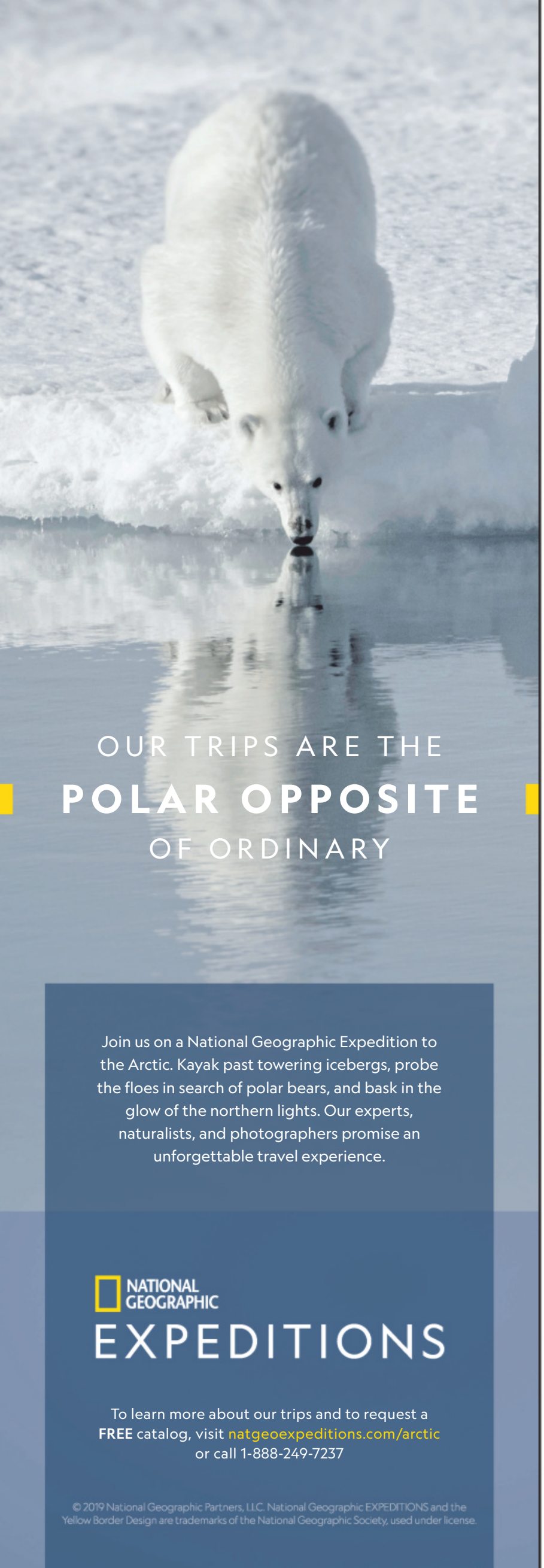


THIS PHOTOGRAPH WAS THE HARDEST I've ever had to make. As I stood underneath that tree in Australia's Northern Territory, I thought about what the salt-water crocodile hanging from it had lived through. Born some 50 years ago, the reptile had grown from a two-and-a-half-ounce hatchling into a 15-foot-long colossus weighing 1,000 pounds. It hatched toward the end of a 25-year period of intensive commercial hunting that had pushed the species to the brink of extinction. It was the perfect predator, and I feared that I was somehow celebrating its death.

I made this photograph to commemorate an epic hunt and the men who took part in it. Some might assume that because they took its life, the men standing beside the crocodile have no respect for the animal. But I've learned that it's possible for hunters to love the creatures that they kill—and to be part of a solution that saves a species. This is the complex situation I wanted to explore when I documented crocodile hunting for *National Geographic*.

In 1971 saltwater crocodiles became protected in the Northern Territory. As part of the government's strategy of "incentive-driven conservation," a set amount of eggs may be collected from the wild, with the hatchlings eventually being farmed for their skin; and a limited number of crocodiles, including those that have threatened humans, may be hunted each year. Even with that regulated harvesting, the wild saltwater crocodile population in the Northern Territory has grown from about 5,000 in the late 1960s to approximately 100,000 today, a number scientists say is close to what it once was. To put this into perspective: Fifty years ago, at the height of commercial hunting, people would swim in the region's rivers and lagoons; now no one dares.





If you purchased Kona Beer you could get up to $20 from a proposed class action settlement

The Court has tentatively approved a proposed settlement in *Broomfield v. Craft Brew Alliance, Inc.*, No. 5:17-cv-01027-BLF, a class action alleging Craft Brew Alliance, Inc. ("CBA")'s packaging and marketing of its Kona Beer products portrayed the beer as being brewed in Hawaii, when Plaintiffs claimed they were not.

If you purchased Kona Beer between February 28, 2013 through June 14, 2019, you may be entitled to a cash payment as part of the settlement up to **$20** with proof of purchase or up to **$10** without proof of purchase.

To receive a monetary payment, you **must submit** a Claim Form by October 7, 2019. Claim Forms can be found at www.konabeersettlement.com or can be requested by calling 1-888-332-0551.

If you do not want to be bound by the Settlement, you must submit a written Request for Exclusion. If you exclude yourself, you cannot get a payment, but you preserve the right to sue CBA for the claims alleged in the lawsuit. Any Request for Exclusion must be submitted by October 7, 2019, either online at www.konabeersettlement.com or mailed and postmarked to *Broomfield v. Craft Brew Alliance, Inc.* c/o CPT Group, Inc. 50 Corporate Park, Irvine, CA 92606.

You can also object to the Settlement. An objection is a written statement explaining why do not think the Settlement is fair. Any objection must be submitted to the Court by October 7, 2019. You cannot object if you exclude yourself from the Settlement.

There will be a final approval hearing for this settlement to determine whether the Court will approve of the settlement, scheduled for December 19, 2019 at 1:30 p.m. in the Robert F. Peckham Federal Building, Courtroom 3, located at 280 South 1st Street, Courtroom 3 San Jose, CA 95113.

This Notice summarizes the Settlement. For the precise terms and conditions of the Settlement, please see the Settlement Agreement available at www.konabeersettlement.com, by contacting Class Counsel whose contact information can be found at www.konabeersettlement.com, by contacting the Settlement Administrator at 1-888-332-0551, by accessing the Court docket in this case, for a fee, through the Court's Public Access to Court Electronic Records (PACER) system at https://ecf.cand.uscourts.gov, or by visiting the office of the Clerk of the Court for the United States District Court for the Northern District of California, 280 South 1st Street, Courtroom 3 San Jose, CA 95113, between 9:00 a.m. and 4:00 p.m., Monday through Friday, excluding Court holidays.

PLEASE DO NOT TELEPHONE THE COURT OR THE COURT CLERK'S OFFICE TO INQUIRE ABOUT THIS SETTLEMENT OR THE CLAIM PROCESS

WHAT HAPPENED NEXT WAS STRAIGHT OUT OF HOLLYWOOD: THE CROCODILE BEGAN PULLING THE BOAT.

I made eight trips over four years to the Northern Territory, spending months with the professional crocodile hunters in this photograph: Roger Matthews on the left and Aaron Rodwell on the right. In that time I learned several things. Both men love crocodiles dearly; killing crocodiles is not something they celebrate, though they admitted to feeling a thrill in the moment; and the danger to the hunter is roughly equivalent to the danger faced by the animal. Hunters need to get close to a crocodile to kill it because shooting it from a distance won't work. Unless the shot is perfect—a centimeter or so behind the ear, straight to the brain—the crocodile will be able to retreat underwater, where it will bleed to death, a fate that horrifies most hunters I know. So hunters risk their lives to prevent it. But that doesn't mean that death comes quickly.

This animal was a "problem crocodile," in official parlance. It had almost taken a woman in Arnhem Land—Aboriginal land—while she was collecting file snakes along the bank of a lagoon. Her husband, Samuel Nayinggul, requested that the animal be removed, and Aaron obtained an emergency permit from wildlife officials.

The hunt began just before sunset and lasted until around three in the morning. Roger steered his small aluminum boat through the lagoon while Aaron shone a powerful halogen spotlight on the water's surface. Samuel served as guide. I was in the back of the boat. Four hours into the search they finally spotted the crocodile. Aaron struck it with a homemade harpoon attached to a spool of venetian blind cord, but the crocodile dislodged the hook and disappeared underwater. Another hour passed.

Then Roger said to me, "Sit down now." Aaron moved to the boat's prow and stood there with the spotlight in one hand and in the other his makeshift weapon, which was designed to hook the animal, not kill it. Aaron focused the spotlight on the crocodile while Roger inched the boat forward. When we were within two or three feet, Aaron thrust the harpoon into its neck. That made the crocodile mad as hell. In an instant the boat spun sideways, knocking Aaron off his feet and onto the floor of the boat.

What happened next was straight out of Hollywood: The crocodile began pulling the boat—not rapidly or violently but just enough to demonstrate how strong it was. That crocodile pulled us around the lagoon for more than two hours. When it finally resurfaced, it was clearly exhausted. Roger grabbed a snout rope, which he tried to loop over the crocodile's upper jaw to subdue it.

Again, the crocodile had other plans. It launched itself at the boat and bit the side, thrashing our 17-foot vessel from side to side like a dog with a toy. Luckily, it didn't crush the boat or dump us in the water. After a long struggle to get the snout rope on, Roger and Aaron managed to pull the crocodile's head up onto the side of the boat. Roger then wrapped duct tape around the crocodile's jaws. Once the crocodile was secure, they placed a piece of burlap over its eyes to calm it and Roger used a .22-caliber revolver to end its life. I felt an overwhelming sense of sadness knowing that this magnificent creature was no more.



Death can be both tragic and beautiful, and I spend a good deal of time trying to make photographs that show this. I know I wouldn't have been able to take this photograph if Roger or Aaron had seemed happy or triumphant. But they didn't. Instead we all shared an eerie moment of silence.

After this picture was taken, the crocodile was dismembered. Roger and Aaron removed its head, skin, and tail. Aaron salted the skin, rolled it up, and placed it into a cooler along with the head. Later in Darwin, the largest city in the Northern Territory, the head was treated with chemicals to remove its flesh. The skull later sold for around $2,500. The skin was sent to a tannery in South Australia and sold for some $5,000. That was their pay.

The man who had requested the crocodile's removal received peace of mind—and the tail, for its meat. □

Trevor Beck Frost is a photographer and filmmaker from Richmond, Virginia. This is his second story for the magazine.

1,200

Yearly hunting limit for saltwater crocodiles in the Northern Territory, less than 2 percent of the total population. In addition, up to 90,000 eggs are harvested from the wild to be farmed.

NGM MAPS

THE NEW COLD WAR

AS THE ICE MELTS, OLD RIVALS SCRAMBLE FOR POSITION.

PAGE 50

THE ARCTIC IS HEATING UP

Imagine the top of the world without ice. It could happen

AN ARCTIC MYSTERY

A British team vanished trying to find the Northwest Passage in the 1840s. Now there are new clues to what happened. PAGE 100

EYES ON THE ICE

In Greenland, researchers from around the world document the warming Arctic and share a sense of community. PAGE 104

ALONE WITH WOLVE

In a 30-hour solo encounter with a wo our writer gains a new appreciation f predators of the tundra. PAGE 1

THE CARBON THREAT

THAWING TUNDRA WILL SPEED UP WARMING WORLDWIDE.

PAGE 74

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sooner than you think.

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olf pack,
or these
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BEFORE IT MELTS

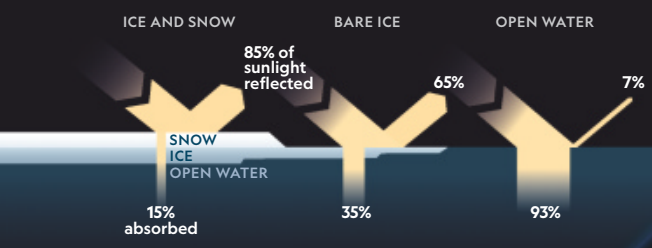
As ice and traditions disappear, Inuit use camping trips to teach their children how to live off the land—and preserve native culture. PAGE 134

NORTH OF THE ARCTIC CIRCLE, our planet is covered by an implacable frozen mass—a sea, as it turns out—that humans have long struggled to explore, understand, and ultimately subdue. From our pursuit of the Arctic's unique animals to our attempts to sail its icy passages to our obsessive quest to reach its desolate pole, we have found the Arctic irresistible and unyielding. Until now. Scientists say that by the middle of this century, rising temperatures could strip away the Arctic's fortress-like ice each summer, unlocking resources and shipping lanes while increasing political tensions, affecting people and animals, and potentially speeding up climate change. We sent writers and photographers to document how this enigmatic region is changing, who and what will feel the impact, and why it matters.

TODAY'S WARMING

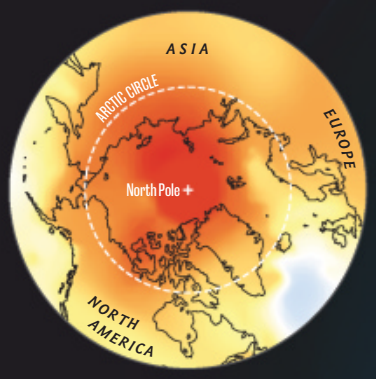
A VICIOUS CYCLE

Snow and ice reflect most incoming light, but open water is less reflective, so it absorbs more heat. More melting causes more open water, a feedback loop that leads to even more warming.



IT'S ALREADY WARMER

The Earth's average surface temperature has risen 1°C (1.8°F) since the 1880s. But the Arctic has warmed more than twice as fast—the past five years have been the hottest on record.

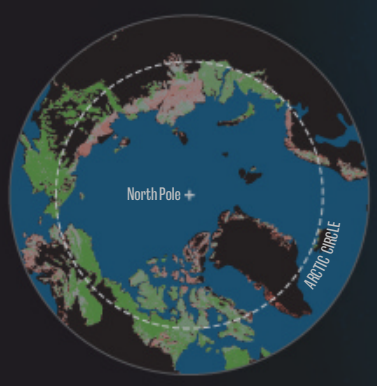


Temperature anomaly
2009–2018

°C	°F
+3.0	+5.4
+2.0	+3.6
+1.0	+1.8
0.0	0.0
-1.0	-1.8

IT'S ALREADY GREENER

The tundra is one of the fastest warming ecosystems on Earth. Shrubs are growing taller and spreading north—an early sign of a greener Arctic.



Change in tundra
2000–2016

- More vegetation
- No change
- Less vegetation

TOMORROW'S ICELESS SUMMER

End of the ice nursery
Young sea ice that once drifted to the pole no longer forms in the shallow seas along Russia's northern coast. In 2018 only a fraction reached mid-ocean.

An iceless Bering Sea
By mid-century this sea will be open most of the year. Algae that grow on ice—and support a food web extending to fish and whales—will be gone.

Northern Sea Route
This well-established corridor will be completely ice free for several months each year. In 2017 a vessel traversed the passage without an icebreaker for the first time.

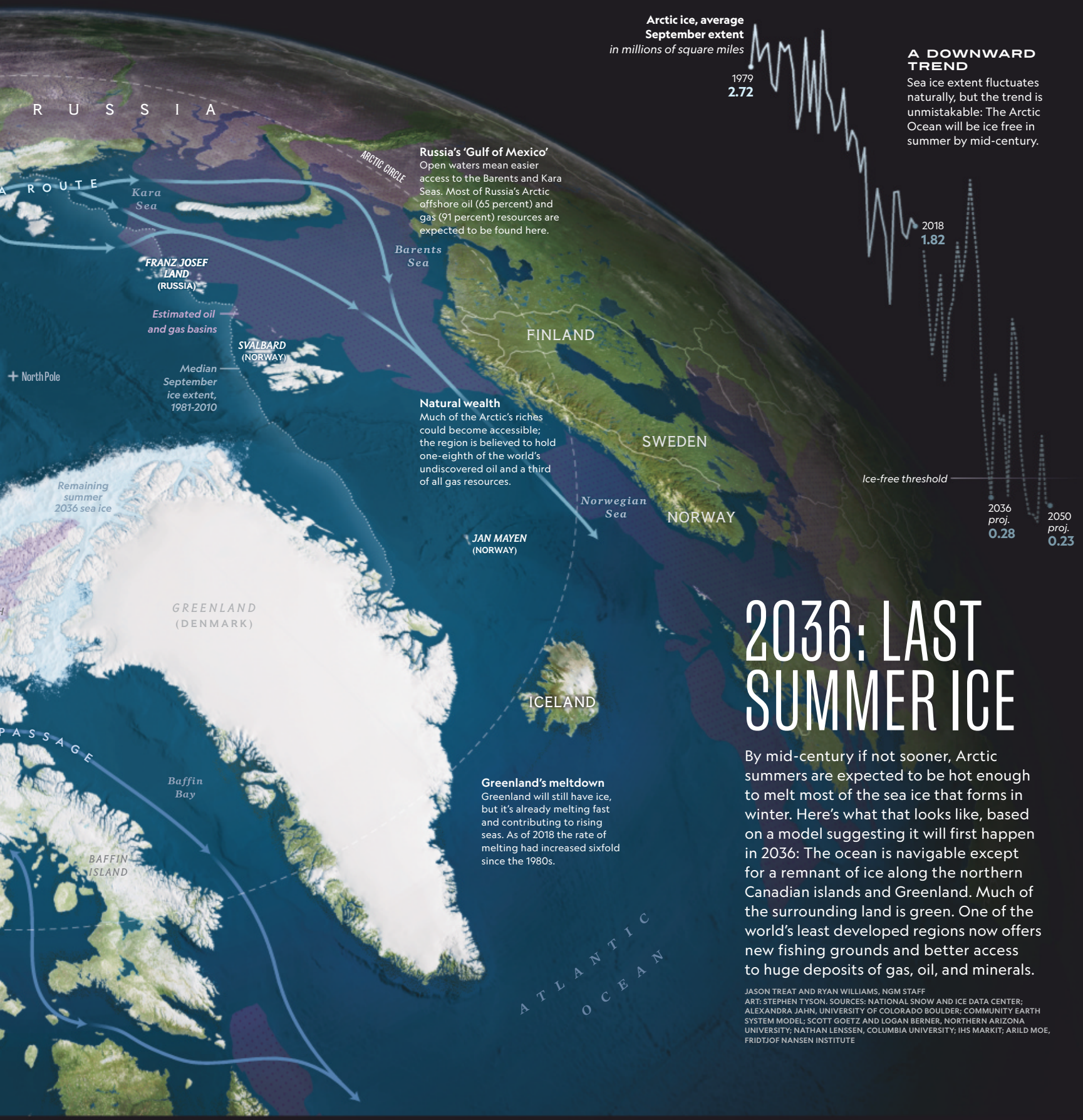
Estimated oil and gas basins

"Ice free," defined
Scientists call the Arctic ice free when less than a million square kilometers (386,000 square miles) of summer ice remain. Last to go: the ice off Canada and Greenland.

Northwest Passage
Nineteenth-century explorers searched for it in vain, and many died in the attempt. By mid-century the passage will be open at least five weeks of the year.

Unfrozen pastimes
Lakes that once supported ice fishing and other recreation will be without ice. In summers they could see increased algal blooms.

NORTHERN SEA
Laptev Sea
ARCTIC OCEAN
Bering Sea
ALASKA (U.S.)
QUEEN ELIZABETH ISLANDS
NORTHWEST
VICTORIA ISLAND
ARCTIC CIRCLE
PACIFIC OCEAN
CANADA
Hudson Bay



A DOWNWARD TREND

Sea ice extent fluctuates naturally, but the trend is unmistakable: The Arctic Ocean will be ice free in summer by mid-century.

2036: LAST SUMMER ICE

By mid-century if not sooner, Arctic summers are expected to be hot enough to melt most of the sea ice that forms in winter. Here's what that looks like, based on a model suggesting it will first happen in 2036: The ocean is navigable except for a remnant of ice along the northern Canadian islands and Greenland. Much of the surrounding land is green. One of the world's least developed regions now offers new fishing grounds and better access to huge deposits of gas, oil, and minerals.

JASON TREAT AND RYAN WILLIAMS, NGM STAFF
ART: STEPHEN TYSON. SOURCES: NATIONAL SNOW AND ICE DATA CENTER; ALEXANDRA JAHN, UNIVERSITY OF COLORADO BOULDER; COMMUNITY EARTH SYSTEM MODEL; SCOTT GOETZ AND LOGAN BERNER, NORTHERN ARIZONA UNIVERSITY; NATHAN LENSSEN, COLUMBIA UNIVERSITY; IHS MARKIT; ARILD MOE, FRIDTJOF NANSEN INSTITUTE

OPEN FOR BUSINESS

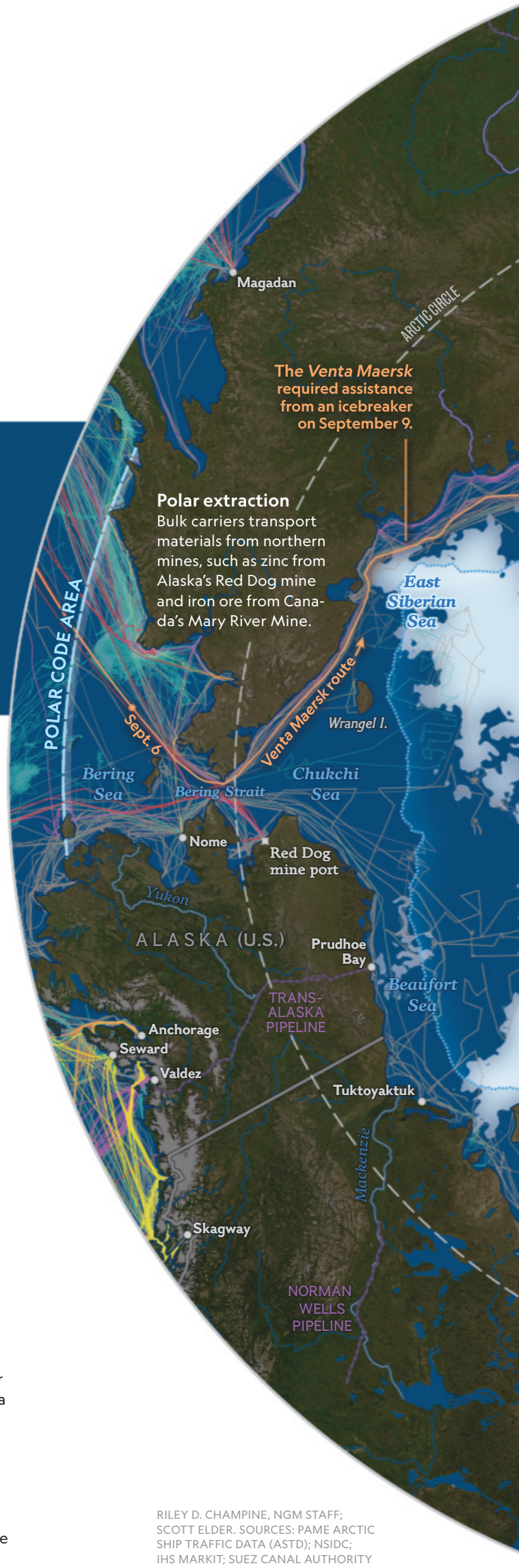
In September 2018, when the area covered by Arctic sea ice shrank to its annual minimum and once again was far below the average of previous decades, hundreds of ships navigated the region. Last year the number of vessels crossing waters governed by the international Polar Code—a set of strict safety and environmental rules—was 879, nearly 60 percent higher than in 2012. As Arctic waters become reliably open, more ships are venturing on new routes.



Ship types in the Arctic
Paths of ships tracked in Sept. 2018

- Fishing vessels **342**
- Oil and gas tankers* **57**
- Container ships **5**
- Bulk carriers **50**
- Cruise ships **28**
- Other **397**

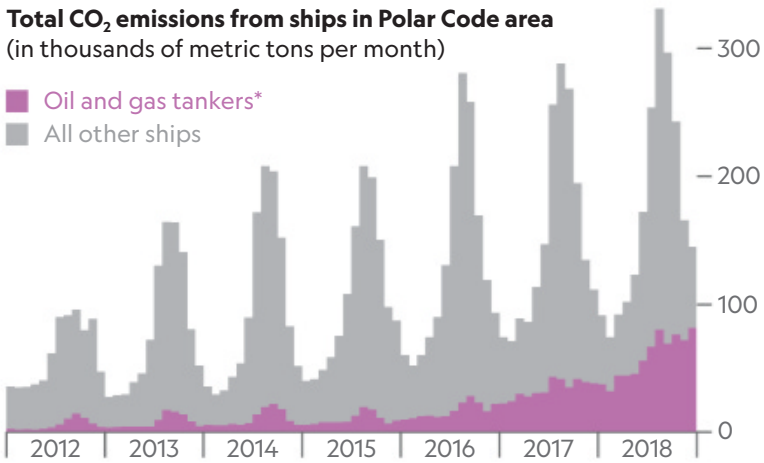
*Includes oil by-products



MORE SHIPS, MORE EMISSIONS

Most Arctic traffic occurs in summer, but new ice-breaking oil and gas tankers are able to operate year-round. These tankers made up just 6 percent of all ships entering Polar Code waters in 2018, but they burned so much fuel that they were responsible for 33 percent of carbon emissions.

Total CO_2 emissions from ships in Polar Code area
(in thousands of metric tons per month)

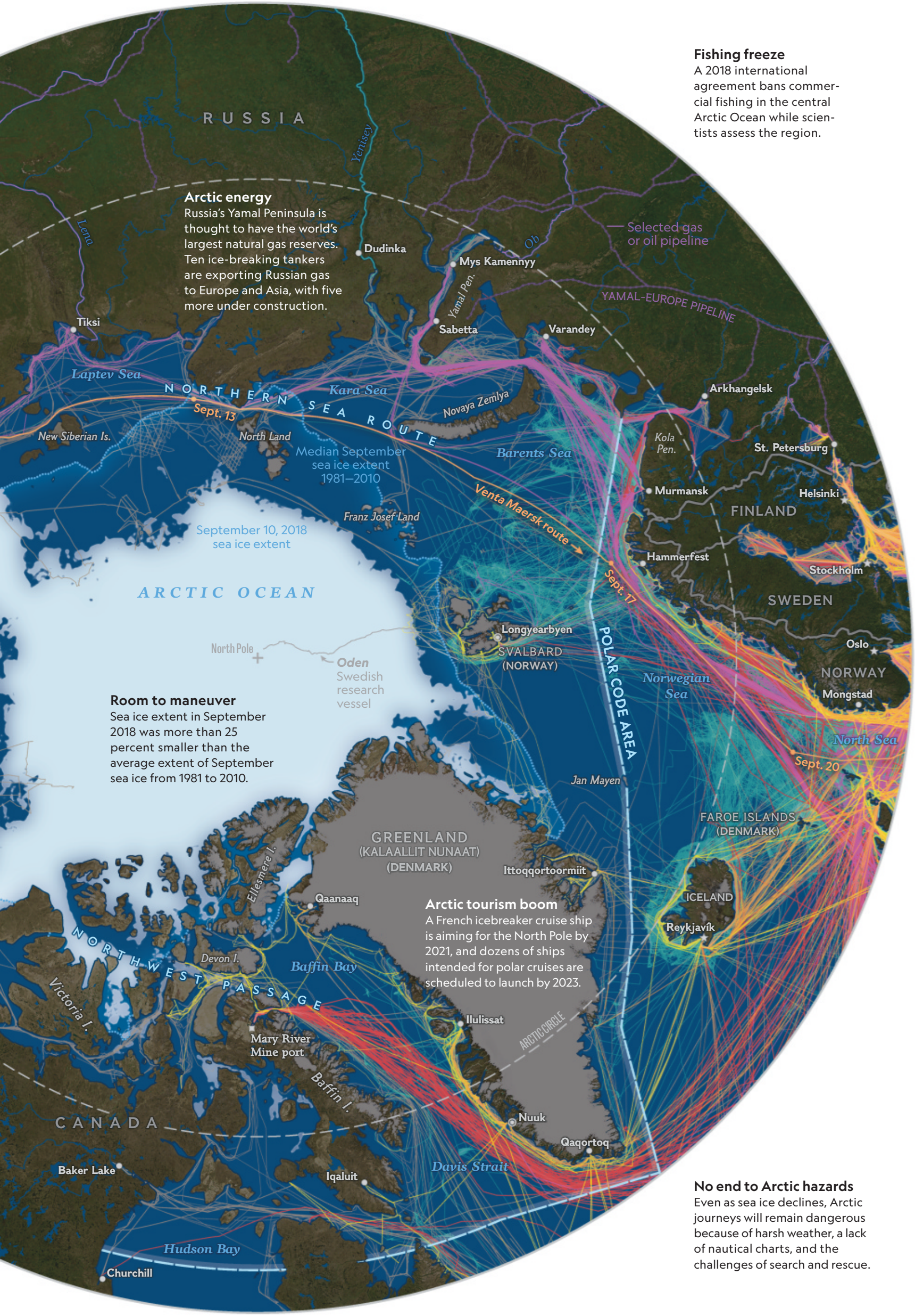




TESTING ALTERNATE ROUTES

Last September the Danish *Venta Maersk* became the first container ship to complete the Northern Sea Route, traveling from East Asia to northern Europe. The journey was 10 days shorter than the southern route through the Suez Canal, but it required the help of a Russian icebreaker. Arctic shipping routes aren't expected to be cost-effective until the region is more ice free.

RILEY D. CHAMPINE, NGM STAFF; SCOTT ELDER. SOURCES: PAME ARCTIC SHIP TRAFFIC DATA (ASTD); NSIDC; IHS MARKIT; SUEZ CANAL AUTHORITY



Fishing freeze
A 2018 international agreement bans commercial fishing in the central Arctic Ocean while scientists assess the region.

Arctic energy
Russia's Yamal Peninsula is thought to have the world's largest natural gas reserves. Ten ice-breaking tankers are exporting Russian gas to Europe and Asia, with five more under construction.

Room to maneuver
Sea ice extent in September 2018 was more than 25 percent smaller than the average extent of September sea ice from 1981 to 2010.

Arctic tourism boom
A French icebreaker cruise ship is aiming for the North Pole by 2021, and dozens of ships intended for polar cruises are scheduled to launch by 2023.

No end to Arctic hazards
Even as sea ice declines, Arctic journeys will remain dangerous because of harsh weather, a lack of nautical charts, and the challenges of search and rescue.



Canadian soldiers climb on the wreckage of a plane, roughly a thousand miles south of the North Pole, to scout the area during an Arctic survival course on Cornwallis Island. As the Arctic warms and tensions over its future rise, the Canadian and U.S. militaries have stepped up operations in the region.

THE NEW

BY **NEIL SHEA**

PHOTOGRAPHS BY **LOUIE PALU**



AS THE ARCTIC THAWS, NATIONS ARE RACING TO CONTROL RESOURCES AND SHIPPING ROUTES BURIED BENEATH THE ICE. HERE'S HOW CLIMATE CHANGE IS SETTING THE STAGE FOR CONFLICT AT THE TOP OF THE WORLD.

COLD WAR





U.S. soldiers eat high-calorie rations to help their bodies deal with the cold at the Northern Warfare Training Center in Alaska, where the Army conducts cold-region training. The soldiers learn tactics derived from the Winter War, fought between Finland and the Soviet Union in World War II.



Some 400 U.S. soldiers practice parachute jumps near Alaska's Fort Greely. The multinational exercise, which includes Canadian forces, prepares troops for the rigors of large, coordinated operations in extreme cold conditions.



LATE ON A GRAY NOVEMBER AFTERNOON Marvin Atqittuq, a newly elected patrol commander in the Arctic community of Gjoa Haven, stood on the frozen sea outside town and called his troops in for a meeting. A frigid wind flicked snow in from the south, and it was about 20 below zero, cold but not that cold for the Arctic. The company of some 20 Inuit men and a few women gathered around with rifles slung over their shoulders, dressed in hand-sewn jackets of caribou hide or pants made of polar bear fur or wearing the usual store-bought stuff, which was far less warm but *namuktuk,* good enough for now. ¶ Atqittuq (pronounced At-kee-TUK) pulled on a pair of sealskin gloves and outlined the plan for the day. The group was part of the Canadian Rangers, a reserve component of Canada's armed forces, and Atqittuq would now lead them on his first mission as their commander: a weeklong patrol by snowmobile down the treeless coast of King William Island. There would be



Marines simulate seizing a building in Utqiaġvik, Alaska, the northernmost city in the United States. Marine Corps commandant Gen. Robert Neller recently told senators that after years of focusing on the Middle East and Pacific, the Marines "had gotten back into the cold-weather business."

Photography for this story was supported by grants from the John Simon Guggenheim Memorial Foundation and the Pulitzer Center.



GPS training, military-style target practice, search-and-rescue scenarios, and plenty of hunting and ice fishing.

I stood at the edge of the circle, rubbing ice from my eyelashes. It was too cold to take notes, so I watched faces and read the frostbite scars, little badges of honor that told of lives spent outdoors on one of the planet's most unyielding landscapes. The group soon broke up and began smoking last cigarettes before the long ride into darkness. Atqittuq walked over to ask whether I was warm enough. He was tall, broad shouldered, laughed easily. He'd been a ranger for many years before the others had voted him their new commander. In a friendly way, he warned me not to fall asleep on the journey ahead.

It happened, he said. Sometimes people tumbled off their snowmobiles and went missing. He reminded me that there was currently no cell service on the island or anywhere else in the territory of Nunavut—three times the size of Texas. "If anything happens and you get separated, just sit tight till someone comes back for you," he said. "And try not to meet any polar bears."

The rangers are called "Canada's eyes and ears in the north," and their units have been patrolling the country's outermost regions since the 1940s. Most rangers in the far north are indigenous volunteers, and over the years they've acted as scouts, participated in war games, and helped regular troops learn to build igloos, navigate the tundra, and generally stay alive in the cold. Their role, like the far north itself, isn't well-known, and the rangers have always managed to keep going on shoestring budgets and hand-me-down equipment, including government-issued bolt-action rifles made in the 1940s and stamped with the British crown.





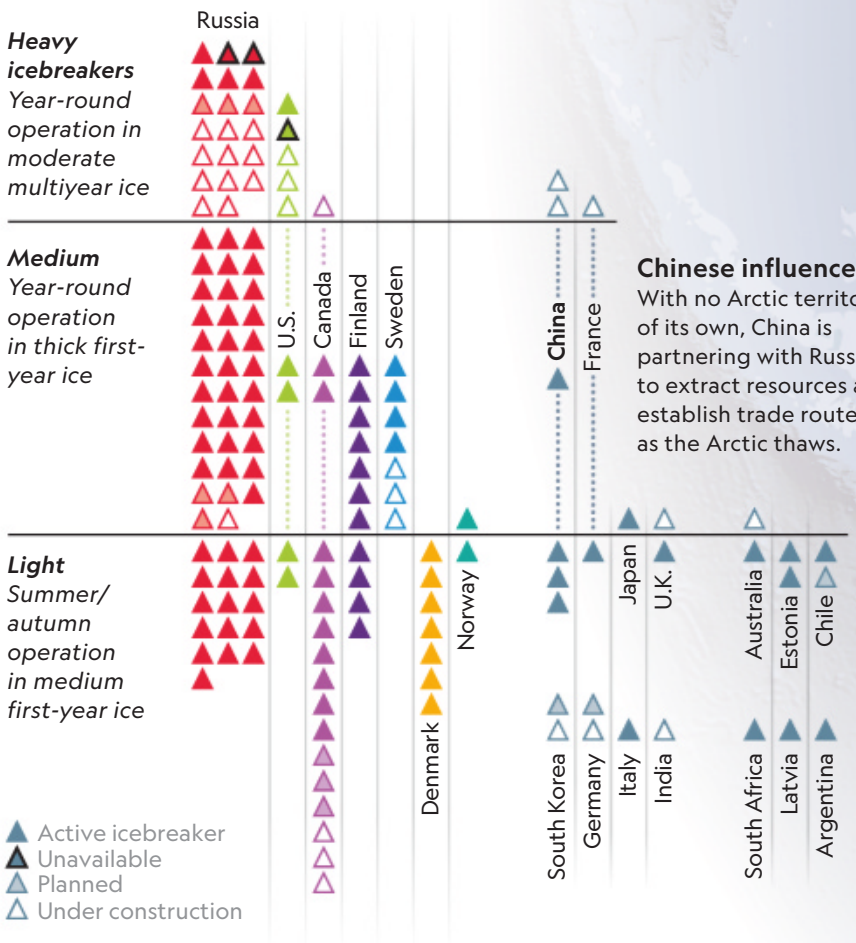
Susie Hiqinit (left) and Andy Issigaitok (above), reservists with the Canadian Rangers, serve alongside many other Inuit. These rangers share their knowledge of Arctic survival with other members of Canada's military, teaching traditional Inuit techniques such as hunting, navigating, and building ice caves.

ARCTIC ASSETS

Once considered nearly impenetrable, the Arctic is taking on new strategic importance as climate change melts its icy armor and trillions of dollars of resources become accessible. The eight nations that encircle the region are scrambling to assert and defend their claims over the Arctic, which remains one of the most daunting landscapes to project power on the planet.

THE RACE TO BREAK THE ICE

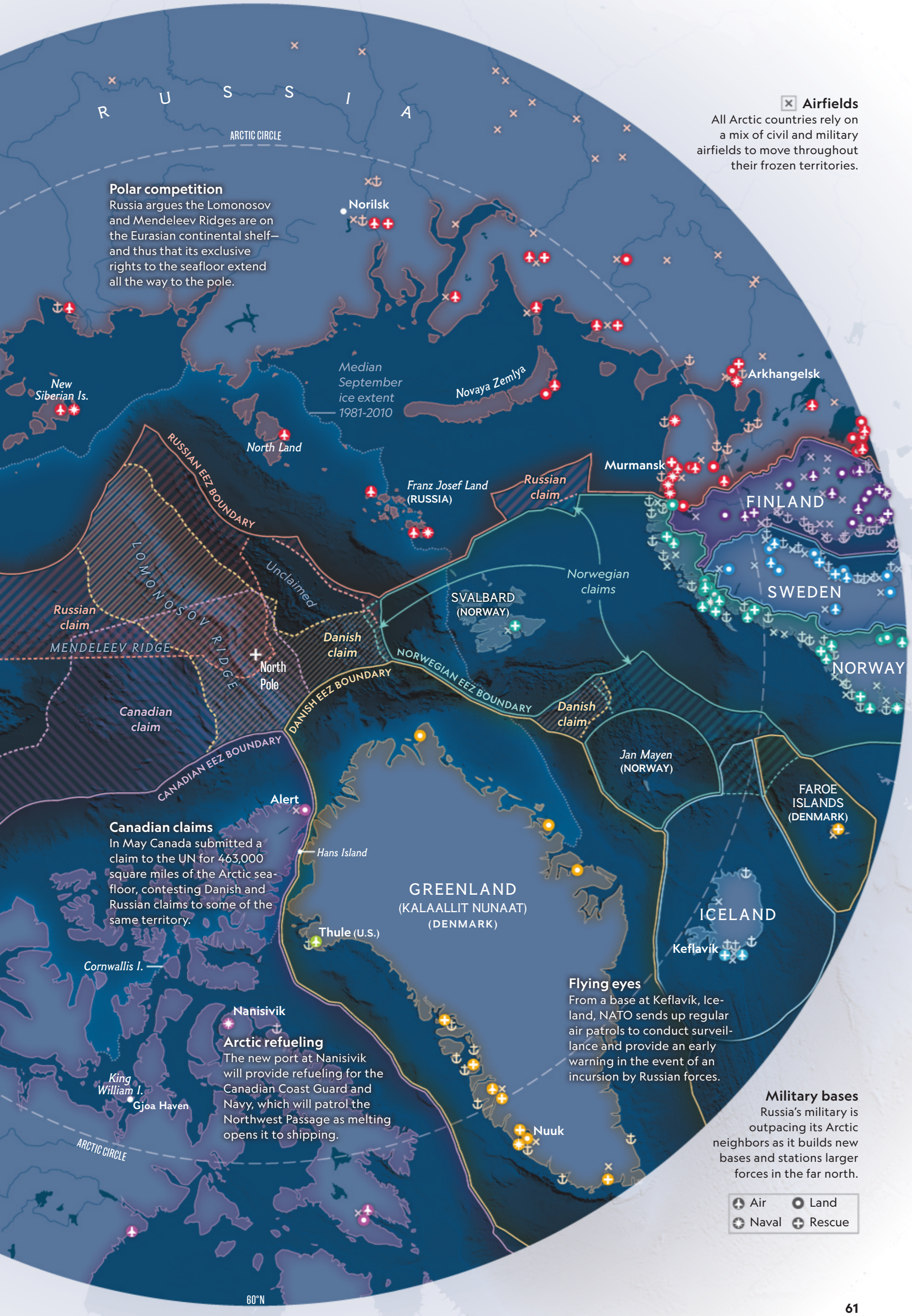
Icebreakers are key tools for projecting power in the Arctic, plowing through sea ice so ships can follow in their wake. Russia has more icebreakers than any other nation; China is also investing substantially in them. The U.S. has just one operational heavy icebreaker, used mostly in Antarctica.



Chinese influence
With no Arctic territory of its own, China is partnering with Russia to extract resources and establish trade routes as the Arctic thaws.



JASON TREAT AND RILEY D. CHAMPINE, NGM STAFF; SCOTT ELDER. SOURCES: JANE'S BY IHS MARKIT; OFFICE OF SENATOR DAN SULLIVAN; NATIONAL GEOSPATIAL-INTELLIGENCE AGENCY; U.S. COAST GUARD OFFICE OF WATERWAYS AND OCEAN POLICY; INTERNATIONAL BOUNDARIES RESEARCH UNIT


RUSSIA
ARCTIC CIRCLE
Polar competition
Russia argues the Lomonosov and Mendeleev Ridges are on the Eurasian continental shelf—and thus that its exclusive rights to the seafloor extend all the way to the pole.
Norilsk
Airfields
All Arctic countries rely on a mix of civil and military airfields to move throughout their frozen territories.
Median September ice extent 1981-2010
New Siberian Is.
Novaya Zemlya
Arkhangelsk
North Land
RUSSIAN EEZ BOUNDARY
Franz Josef Land (RUSSIA)
Russian claim
Murmansk
FINLAND
LOMONOSOV RIDGE
Unclaimed
Norwegian claims
SVALBARD (NORWAY)
SWEDEN
Russian claim
MENDELEEV RIDGE
North Pole
Danish claim
NORWEGIAN EEZ BOUNDARY
NORWAY
DANISH EEZ BOUNDARY
Danish claim
Canadian claim
CANADIAN EEZ BOUNDARY
Jan Mayen (NORWAY)
FAROE ISLANDS (DENMARK)
Alert
Canadian claims
In May Canada submitted a claim to the UN for 463,000 square miles of the Arctic seafloor, contesting Danish and Russian claims to some of the same territory.
Hans Island
GREENLAND
(KALAALLIT NUNAAT)
(DENMARK)
ICELAND
Thule (U.S.)
Keflavík
Cornwallis I.
Flying eyes
From a base at Keflavík, Iceland, NATO sends up regular air patrols to conduct surveillance and provide an early warning in the event of an incursion by Russian forces.
Nanisivik
Arctic refueling
The new port at Nanisivik will provide refueling for the Canadian Coast Guard and Navy, which will patrol the Northwest Passage as melting opens it to shipping.
King William I.
Gjoa Haven
Nuuk
ARCTIC CIRCLE
60°N
Military bases
Russia's military is outpacing its Arctic neighbors as it builds new bases and stations larger forces in the far north.
Air
Land
Naval
Rescue

U.S. soldiers practice climbing a hill while wearing skis at Alaska's Northern Warfare Training Center, where troops learn a range of skills—from dressing for the extreme cold and basic snowshoeing to skiing with a rifle and towing a 200-pound sled.



Around the time of my visit, though, the Canadian government had been reappraising the rangers. Rumblings about an international scramble to stake new claims in the warming Arctic and on its vast trove of untapped resources had prompted politicians in Ottawa to promise the rangers better gear and funds to recruit more volunteers. Meanwhile U.S. military officials also were interested in the program, with an eye toward creating something similar in Alaska.

Atqittuq welcomed the attention. He was raised in the Arctic and was now raising his own son there, so he understood the different ways the far-off government could go from friendly to fickle to forgetful. But this time it wasn't hard to guess what was on politicians' minds: After years spent ignoring the fact that the Arctic is warming faster than any other place on the planet, Canada was finally coming around.

"We Inuit have been talking about this climate change stuff for a long time," Atqittuq told me before we headed out onto the tundra. "Now the government's catching up, and they want us to keep a lookout. Well, OK. We're proud Canadians." Then he grinned. "Just wish we were Canadian enough to get good phone service, eh?"



IN EARLY MAY, U.S. SECRETARY of State Mike Pompeo traveled to Rovaniemi, the capital of Finland's northernmost province, to deliver a speech to the Arctic Council, a group made up of the eight nations that border the Arctic, plus representatives of the region's indigenous peoples. For about 20 years the council has encouraged collegial debate, cooperation, and a progressive perspective on climate change. Pompeo's appearance, as the emissary of an administration that is opposed to that approach, made for an awkward moment.

"This is America's moment to stand up as an Arctic nation and for the Arctic's future," Pompeo declared at an event the night before the official meeting. "Because far from the barren backcountry that many thought it to be ... the Arctic is at the forefront of opportunity and abundance."

The speech signaled the end of a truly bizarre rebranding of the Arctic that has been under way for more than a decade. What was once considered a frozen wasteland is now routinely described as an emerging frontier. The Arctic, in other words, is open for business.

For most of human history, the world above 66 degrees latitude has remained largely out of play for large-scale commerce. Explorers, speculators, and scientists long believed rich resources and shipping routes lay hidden beneath the Arctic's ice and snow, but the true nature of its wealth was obscured by the same deadly cold, debilitating darkness, and enormous distances that blocked its exploitation.

Today the Arctic landscape is greener than you are probably comfortable imagining, with fewer caribou and reindeer, more mosquitoes, warmer summers. The most visible and disturbing change has come at sea, where summer sea ice—the floating expanse that covers much of the Arctic Ocean during the region's brief thaw—has been disappearing at an astonishing rate.

While this floating sheet always shrinks in warm months and grows again with the return of the cold, the scale of ice loss has been unprecedented, and some researchers believe it's speeding up. NASA scientists estimate that on average



LEFT

U.S. aviators practice deploying signal flares in the event of a crash or forced landing. With millions of square miles of empty, inhospitable landscape, the Arctic presents huge logistical challenges for search-and-rescue operations.

BELOW

Canadian aviator Simon Jean stretches out in a fighter trench he has begun to dig by cutting out blocks of ice. The trenches can serve as basic shelters, and the ice blocks can also be used for building igloos.



U.S. Special Forces troops and Marines simulate capturing an Arctic radar station at Point Barrow, Alaska, the nation's northern-most point. Radar stations are key tools for tracking missile launches and incursions by Russian aircraft.



the Arctic loses nearly 21,000 square miles of ice each year, and the experts who prepared the 2014 National Climate Assessment predict the Arctic Ocean will be ice free in summer before 2050.

"It's all happening much faster than anyone thought," said Michael Sfraga, director of the Polar Institute at the Wilson Center in Washington, D.C. "There's an ocean opening before us in real time."

Along the new frontier, the contest will not be about claiming new territory. Except for a few disputed tracts, mostly on the seafloor and including the North Pole itself, the Arctic's borders are settled. Instead nations and corporations are now seeking a share of trillions of dollars' worth of minerals—including gold, diamonds, and rare earth metals—petroleum, natural gas, and fish, as well as access to potentially cost-saving new shipping lanes.

Retreating ice has been followed, in some places, by heavy investment. Russia and Norway have been the most active Arctic nations, spending billions over the past decade on natural gas and oil infrastructure, deep-water ports, and ships capable of navigating the Arctic Ocean's still-icy waters. Meanwhile China has sought its own footholds in the region, backing Russian gas projects and offering development loans to other Arctic nations. The Chinese also are building their own fleet of icebreakers, a clear bet on the future by a nation that lies more than 2,500 miles south of the pole.

By contrast, most Western nations, including Canada and the United States, which together control nearly half the Arctic coastline, have virtually ignored the north. The U.S. has five functioning icebreakers (compared with Russia's 51) and no deep-water ports north of the Arctic Circle. That disequilibrium has, in turn, been dogged by a creeping tension, and the new frontier narrative has been accompanied by one of looming conflict, even the possibility of a new Cold War. These fears, finally felt in the U.S., were the real reason behind Pompeo's appearance at the Arctic Council.

"The region has become an arena for power and for competition, and the eight Arctic states must adapt to this new future," he said. "We're entering a new age of strategic engagement … complete with new threats to the Arctic and its real estate, and to all of our interests in that region."

The problem, of course, was that if Pompeo wanted to think of the Arctic as an arena, presumably where a race might be run, some nations already had a solid head start.

ON KING WILLIAM ISLAND, the rangers traveled west in a long line of snowmobiles. Some pulled wooden sleds, heavy with food, camping gear, and military equipment. I joined the procession on a borrowed machine, and after several frigid hours driving into the enormous night, we reached a frozen lake called Kakivakturvik.

In bright beams of headlamps and headlights, the rangers scattered over the lake and began setting up large canvas tents on the ice. Caribou skins and tarps were dragged in, then foam mattresses, sleeping bags, coolers filled with food.

Soon the tents glowed with lantern light and whispered with the sound of kerosene stoves. Steaming cups of tea were passed around, a few stories shared about favorite sled dogs, and then it was back outdoors. In small groups the rangers fanned out over the lake, chopped holes in the foot-thick ice, and dropped fishnets into the black water.

Across the Canadian Arctic, ranger patrols mix military exercises with traditional activities such as hunting and fishing that are still a necessary part of life in the far north. Over the next several days Marvin's group tried to balance these with the martial stuff of navigation drills and training on GPS devices.

Strong winds hurtled off the frozen sea, and thick fog and clouds hung low over the tundra. The temperature rose toward freezing a couple of times, then fell again and stayed far below zero. All this was typical for late November, and soon our lives collapsed into the small white and gray world around camp.

Days began and ended at the fishnets. The haul of *iqalupik,* arctic char, was so plentiful that soon each tent was flanked by a small stand of stiff pink bodies, stuck tails first into deep drifts of snow. When we got hungry, we simply slipped an arm out the door and snagged a fish. Sometimes we cut it up and made soup. More often we ate it raw, slicing the char into our mouths. Frozen sushi, Marvin called it, fresh and cold, almost tasteless, with a note of steel from the knife blade.

Beyond the nets, our hours vanished into a well of small tasks. In the day's few hours of weak sunlight, there were stoves to tend, ice to melt for drinking water, tents to relocate when the ice below them turned to slush. Snowmobiles regularly broke down in the unforgiving cold. At one

point, a mother polar bear appeared near camp with two cubs, which made the act of heading off alone to relieve oneself—already dismal enough in the puckering cold—an even uglier prospect.

During the mission I shared a tent with Marvin Atqittuq and his father, Jacob, who at 74 was one of Gjoa Haven's most celebrated hunters. Jacob Atqittuq had been born in an igloo and spoke only enough English to make occasional jokes. Over his lifetime he'd survived brutal winters and hungry bears, searing frostbite, boat accidents, even a season of famine that had killed many Inuit. Each morning he woke before us, and at the foot of the broad mattress we all shared, he cooked bannock, a sweet, doughy bread, and softly sang old church hymns in Inuktitut.

One evening, as we lay in our sleeping bags, Marvin told me he'd once tried to leave the Arctic. He'd found a vocational school in southern Canada that offered classes in small engine repair. But years before, Jacob had watched another son taken from home and forced to attend one of Canada's notorious residential schools, where indigenous knowledge and traditions were cruelly repressed. He asked Marvin to stay. Learn the old ways. Keep the family whole.

Marvin didn't regret his decision. He was a father himself and a volunteer fireman in Gjoa Haven. He'd found a job with a company maintaining telephone lines, and he was slowly learning all he could from Jacob. But Jacob also seemed to inhabit a simpler, older Arctic.

The one Marvin knew was complicated. There were fewer opportunities, more drugs. There were social media and the internet. Marvin understood his Arctic was becoming something new. He'd read that the ice was melting, that another war might come north. He knew the weather was different from what he'd known as a child—not necessarily warmer but more unpredictable.

As for the gold rush he kept hearing about, he couldn't see it. "All these things are supposed to be happening," he told me, referring to the predictions of new infrastructure and jobs to harvest the region's hidden riches. "I don't really feel much change. I definitely don't feel like I'm part of it."

The next morning I left camp to scout for caribou with the Atqittuqs and a few others. When a blizzard blew in and swallowed our hunting party, it was Jacob who led us back to camp, using a combination of GPS and some other, inner map. I drove my snowmobile slowly behind Marvin's, nearly blinded by a skin of ice that formed inside my goggles. Soon the world became so intensely white that I could no longer tell where the earth ended and the storm began.

At some point, the balaclava covering my face slipped out of place, exposing an inch of skin. I felt a burning sensation, as though someone had pressed a hot coin to my cheek, but I was busy keeping up. Hours later, in our tent, Jacob saw the burn. He pressed his thumb to it. "Good," he said.

CANADA AND THE U.S. CONTROL NEARLY HALF THE ARCTIC COAST, BUT UNTIL NOW THEY HAVE VIRTUALLY IGNORED THE NORTH.

THE OPENING OF THE NEW frontier can be traced to a calm morning in August 2007, when a pair of Russian submersibles dropped 14,000 feet to the bottom of the Arctic Ocean and planted a flag made of titanium at the North Pole. Images broadcast around the world of the Russian tricolor on the seabed drew quick condemnation in the West.

It had been one of the hottest years on record, and just a month later scientists monitoring the ocean by satellite announced that sea ice had shrunk to the lowest extent ever witnessed. "It was the largest Arctic ice loss in human history and was not predicted by even the most aggressive climate models," said Jonathan Markowitz, a professor of international relations at the University of Southern California. "This shock led everyone to suddenly understand that the ice was rapidly disappearing, and some nations decided to start making moves."

Today Russia has become, by most measures, the dominant power in the Arctic. It has the world's largest fleet capable of operating year-round in extreme northern waters and maintains dozens of military bases above the Arctic Circle. The U.S. maintains one base in





The attack submarine U.S.S. *Connecticut* protrudes through an ice floe in the Beaufort Sea. For decades the U.S. and Russian navies have jockeyed for position in the Arctic. Now China is ready to enter the fray, investing in icebreakers and other technology as melting opens new, potentially lucrative shipping lanes.

the Arctic, an airfield, on borrowed ground in northern Greenland.

Russia has stationed new troops in the north, increased submarine activity, and returned warplanes to Arctic skies, where they now routinely buzz NATO airspace. But Markowitz and several other researchers told me Russian activity in the north was a mirror more of internal plans than of global ambitions.

Two million Russians inhabit the country's Arctic territory, which has several large cities, including Murmansk and Norilsk. The combined Arctic populations of Canada and the U.S. equal less than a quarter of that number. In the U.S., the largest Arctic town, Utqiaġvik, formerly Barrow, is home to just over 4,000 people.

Russians depend heavily on extracted resources, Markowitz explained. They view the Arctic "as their strategic future resource base."

According to Yun Sun, a senior fellow at the Stimson Center, in Washington, D.C., Chinese expansion into the Arctic follows a similar resource-focused strategy, not a territorial one. Beyond its investments in Russian oil and gas ventures, she said, China is specifically interested in gaining access to new sea-lanes that could reduce transit times between Asian ports and European markets by as much as two weeks.

Last January the Chinese government published a white paper that outlined its northern intentions. In it, China described itself as a "near-Arctic state" that hoped to collaborate with other nations to build a "Polar Silk Road" dedicated to commerce and research. "It's something to watch carefully," Sun said. "I will give you the literal translation of what the Chinese said to me: 'We know that we don't have claims in the Arctic, but if there's anything in the Arctic that we can get, we don't want to be left out.' "

DURING MY TRAVELS along the new frontier, Cold War analogies always fell flat. Easier to grasp was the Arctic's overall absence from the North American mind. Over decades the U.S. and Canada had never bothered to develop their northern territories or invest in their people. Even Pompeo's speech, with language of opportunity and marketplaces, felt more like a warning than a plan—the protest of a player arriving late to the game.

This attitude is often insulting, even painful, to the Arctic's indigenous people, especially because such promises of opportunity have nearly always excluded them. Joe Savikataaq, the premier of Canada's Nunavut Territory, echoed Marvin Atqittuq when he told me the Inuit had been left out of plans for the new Arctic. "We're happy and proud to be part of Canada," he said, "but we feel like the poor brother that gets scraps."

Savikataaq listed several categories in which northern communities lag behind southern ones—health care, job creation, technology, college graduation. Then he listed a few where the north was ahead: loss of ice, cost of living, rate of warming, rate of suicide. Whatever's coming this time, he said, it will hit us first. "I can't speak too much about what Russia or China or the U.S. want to do or might do. We're so small and our resources are so limited that we're just a bystander," Savikataaq said. "All we can do is adapt as best we can."

ABOUT A WEEK INTO THE rangers' mission the weather finally broke, and Marvin Atqittuq decided it was time to shoot Russians. He and Sgt. Dean Lushman, a former Canadian infantryman who had become an instructor with the ranger program, hauled out a sheaf of brownish paper targets, stapled them to sticks, and planted half a dozen in the snow outside our camp. Each bore the printed image of a charging soldier, his mouth open in a yell, his rifle mounted with a bayonet. Lushman called them his "Commie squad."

The targets had been developed for NATO forces during the Cold War. Standing shoulder to shoulder at the foot of a small hill, they were the tallest objects around for miles, so obvious against the snow it didn't seem possible to miss.

Atqittuq drew a line in the snow 100 yards away and arranged his troops along it. He gave each a handful of bullets, and the rangers knelt onto sealskins or parkas and began firing their clumsy, antique rifles. Atqittuq said age was their only advantage: The old rifles had so few moving parts that they usually didn't freeze.

I asked Lushman, who had done several combat tours in Afghanistan, if he thought a new Cold War was coming to the north. He laughed.

"Man, look at this." He spread his arms wide, taking in the empty tundra, the rangers, the paper Russians. "What would anyone do up here? Tanks driving around, soldiers, planes?" He turned to Atqittuq. "Whaddya say, Marv? You ready to fight the Russians?" Atqittuq grinned up from his notebook. "Too much hassle."

"From a military standpoint, it doesn't make sense, eh?" Lushman said. "You've seen how much time we spend out here just doing basic shit. You've seen how often our stuff breaks down, how much work it takes just to survive. Ain't no war comin' up here."

The Canadian Rangers had been created during the first Cold War, when military planners, worried about ballistic missiles and the space race, had looked at the Arctic and seen a vulnerable back door. But the rangers themselves were never intended to battle invading armies. Even now, the eyes and ears of the north are far more likely to watch for passing ships: the Chinese icebreakers, cargo vessels, and cruise ships that are expected to appear in ever greater numbers as ice disappears.

Paul Ikuallaq, one of the rangers on the firing line, had been volunteering with the program for some 30 years. During the Soviet era he had helped train NATO troops. "It was kind of a shit show," he said.

A barrel-chested, tough-love kind of guy with a rich laugh, Ikuallaq also didn't believe war would come to the north. The *kabloona* soldiers he had taught over the years all went home with ice-numbed fingers and toes, reminders of just how bad war in the cold would be.

"Those guys, some of them didn't even know when they had frostbite on their faces," Ikuallaq said, laughing. "They didn't know they could get even whiter."

While none of the NATO officials I spoke to believed Russia would launch a war in the north, several suggested a conflict might begin somewhere in the south and eventually spread to the Arctic. Some cited Russia's violent takeover of Crimea and China's aggressive moves in the South China Sea.

But many outside the military believe there's still hope for a different Arctic, one that looks less like a Cold War battlefield and more like Antarctica or space. In those regions, both of them also frontiers, international agreements—and distance—dampen the effect of political struggles.

"Countries that have difficulty elsewhere find themselves having to cooperate in cold, dark, dangerous, expensive regions," said Michael Byers, a professor at the University of British Columbia. "This necessity of cooperation leads to a practice of cooperation."

RUSSIA HAS BECOME THE DOMINANT ARCTIC POWER, WITH THE LARGEST ICEBREAKER FLEET AND DOZENS OF MILITARY BASES.

ON OUR LAST EVENING IN camp, well after the sun had set, a small group of young Inuit roared in on snowmobiles. The rangers greeted them, cigarettes began to glow. It was cold but not that cold. The men had been hunting caribou somewhere in the west, without luck.

Suddenly one of the newcomers stumbled into the crowd. He was upset and told of a young man who had been riding in the sled he was towing. The passenger had disappeared. He must have fallen off somewhere out on the tundra. Marvin and other rangers asked for more details, but the young man could only shrug and point. Here was the sort of search-and-rescue mission the rangers had trained for. But before Atqittuq could organize it, a pair of rangers suited up and throttled off.

We watched their headlights streak into the darkness, grow fainter, vanish. Then most of us wandered back to our tents to wait and listen for the whine of returning machines. We made tea. Marvin seemed concerned but not overly so; the missing Inuit had been raised in the Arctic and knew what to do if he found himself alone on the ice. I thought of the bears spotted a couple of days before and tried to imagine what the young man was doing out there. Maybe he was singing hymns. □

Writer **Neil Shea** profiled Tokyo in the April issue. Photographer **Louie Palu** received a Guggenheim Fellowship to photograph the military in the Arctic. This is his first story for the magazine.

THE THREAT BELOW

ARCTIC PERMAFROST IS THAWING MUCH FASTER THAN EXPECTED, RESHAPING THE LAND AND RELEASING CARBON GASES THAT COULD SPEED UP CLIMATE CHANGE.



The Batagaika crater in eastern Siberia, half a mile wide and growing, is the largest of many across the Arctic. As permafrost laced with buried ice thaws, the ground collapses, forming craters or lakes.

BY **CRAIG WELCH**

PHOTOGRAPHS BY **KATIE ORLINSKY**



Methane, a potent greenhouse gas, is bubbling from thawing ground under lakes across the Arctic. In winter, surface ice traps the gas. On this pond near Fairbanks, Alaska, scientists have drilled through the ice and set the escaping methane on fire.



SERGEY ZIMOV, AN ECOLOGIST BY training, tossed a woolly mammoth bone on the pile. He was squatting in mud along the cool, wide Kolyma River, below a towering cliff of crumbling earth. It was summer in eastern Siberia, far above the Arctic Circle, in that part of Russia that's closer to Alaska than to Moscow. There wasn't a speck of frost or snow in sight. Yet at this cliff, called Duvanny Yar, the Kolyma had chewed through and exposed what lies beneath: a layer of frozen ground, or permafrost, that is hundreds of feet deep—and warming fast. ¶ Twigs, other plant matter, and Ice Age animal parts—bison jaws, horse femurs, mammoth bones—spilled onto a beach that sucked at Zimov's boots. "I love Duvanny Yar," he said as he yanked fossils from the muck. "It is like a book. Each page is a story about the history of nature." ¶ Across nine million square miles at the top of the planet, climate change is writing a new chapter. Arctic permafrost isn't thawing gradually, as



Sergey Zimov, right, and his son, Nikita, run an Arctic research station in Cherskiy, Russia, along the Kolyma River. The elder Zimov first figured out that permafrost stores far more carbon than scientists once thought. Some of it is now escaping as temperatures rise.



scientists once predicted. Geologically speaking, it's thawing almost overnight. As soils like the ones at Duvanny Yar soften and slump, they're releasing vestiges of ancient life—and masses of carbon—that have been locked in frozen dirt for millennia. Entering the atmosphere as methane or carbon dioxide, the carbon promises to accelerate climate change, even as humans struggle to curb our fossil fuel emissions.

Few understand this threat better than Zimov. From a ramshackle research station in the gold-mining outpost of Cherskiy, about three hours by speedboat from Duvanny Yar, he has spent decades unearthing the mysteries of a warming Arctic. Along the way, he has helped upend conventional wisdom—especially the notion that the far north, back in the Pleistocene ice ages, had been an unbroken desert of ice and thin soils dotted with sage.

Instead, the abundant fossils of mammoths and other large grazers at Duvanny Yar and other sites told Zimov that Siberia, Alaska, and western Canada had been fertile grasslands, rich with

The nonprofit National Geographic Society, working to conserve Earth's resources, helped fund this article.

herbs and willows. As these plants and animals died, the cold slowed their decomposition. Over time, windblown silt buried them deep, locking them in permafrost. The upshot is that Arctic permafrost is much richer in carbon than scientists once thought.

Now new discoveries suggest that the carbon will escape faster as the planet warms. From the unexpected speed of Arctic warming and the troubling ways that meltwater moves through polar landscapes, researchers now suspect that for every one degree Celsius rise in Earth's average temperature, permafrost may release the equivalent of four to six years' worth of coal, oil, and natural gas emissions—double to triple what scientists thought a few years ago. Within a few decades, if we don't curb fossil fuel use, permafrost could be as big a source of greenhouse gases as China, the world's largest emitter, is today.

We aren't accounting for that. The UN's Intergovernmental Panel on Climate Change has only recently started incorporating permafrost into its projections. It still underestimates just how wide Pandora's freezer could swing open—and how much havoc that could unleash.

Permafrost's potential to warm the planet is dwarfed by our own. But if we hope to limit warming to two degrees Celsius, as 195 nations agreed to during the 2015 Paris talks, new research suggests we may have to cut emissions eight years sooner than IPCC models project, just to account for the thawing that will be going on.

It is perhaps our least appreciated reason to hasten a transition to cleaner energy: To reach whatever goal we set to combat warming, we'll need to move even faster than we think.

ZIMOV FIRST CAME TO Cherskiy in the 1970s as a college student to help with mapping on an expedition. He loved the stark landscape and isolation and remoteness from Soviet power centers. The dark winters promised time to think. He returned a few years later and founded the Northeast Science Station, at first under the auspices of the Russian Academy of Sciences. Today he owns and runs it with his son, Nikita. It's an improvisational operation run on a shoestring and on secondhand equipment. But the station attracts Arctic scientists from around the world.

One day in the summer of 2018, photographer Katie Orlinsky and I joined Zimov in an aging boat to ferry supplies to a carbon-monitoring facility at Ambarchik Bay, near the mouth of the Kolyma on the Arctic Ocean. The site had originally been occupied by a transit station for prisoners bound for Stalin's gulags, and Soviet-era relics were everywhere. We traversed spongy grasses across a walkway fashioned from a string of old steam radiators. Zimov, bull chested, his long white hair tucked in a beret, probed the ground with a metal shaft as he walked. He's been doing that a lot lately, to check the depth of the hard permafrost.

Permafrost—ground that remains frozen year-round—is capped by a few feet of dirt and plant detritus. Called the active layer, this soil normally thaws each summer and refreezes in winter, protecting permafrost from rising heat above. But in the spring of 2018, a crew working for Nikita found that dirt near the surface around Cherskiy had not iced up at all during the long dark polar night. That was unheard of: January in Siberia is so brutally cold that human breath can freeze with a tinkling sound that the indigenous Yakuts call "the whisper of stars." The Soviets used to land heavy planes on the Kolyma. Soil 30 inches down should have been frozen. Instead it was mush.

"Three years ago, the temperature in the ground above our permafrost was minus 3 degrees Celsius [27 degrees Fahrenheit]," Sergey Zimov said. "Then it was minus 2. Then it was minus one. This year, the temperature was plus 2 degrees."

On one level that's not surprising. Earth's five warmest years since the late 19th century have come since 2014, and the Arctic is warming more than twice as fast as the rest of the planet, as it loses the sea ice that helps chill it. In 2017 tundra in Greenland faced its worst known wildfire. Days before we landed in Siberia, thermometers in Lakselv, Norway, 240 miles above the Arctic Circle, recorded a blistering 32 degrees Celsius, or 90 degrees Fahrenheit. Arctic reindeer hid in road tunnels for relief.

Permafrost temperatures globally have been rising for half a century. On Alaska's North Slope, they spiked 11 degrees Fahrenheit in 30 years. Localized thawing of permafrost, especially in villages where development disturbs the surface and allows heat to penetrate, has eroded shorelines, undermined roads and

schools, cracked pipelines, and collapsed ice cellars where Arctic hunters store walrus meat and bowhead whale blubber. Warm summers are already warping life for Arctic residents.

What the Zimovs were documenting in 2018, though, was something different, with implications beyond the Arctic: a wintertime thaw. The culprit, paradoxically, was heavy snow. Siberia is dry, but for several winters before 2018, thick snow had smothered the region. The snow acted like a blanket, trapping summer heat in the soil. At a research site 11 miles from Cherskiy, Mathias Goeckede of Germany's Max Planck Institute for Biogeochemistry found that snow depth had doubled in five years. By April 2018 temperatures in the active layer had risen 10 degrees Fahrenheit.

The phenomenon wasn't limited to Siberia. Vladimir Romanovsky, a permafrost expert at the University of Alaska Fairbanks, had for years watched the active layer freeze completely by mid-January at some 180 research sites in Alaska. But as those places also faced a recent period with heavy snow, the freezing slipped first to February, then to March. In 2018, eight of Romanovsky's sites near Fairbanks and a dozen on the Seward Peninsula, in western Alaska, never fully froze at all.

Globally, permafrost holds up to 1,600 gigatons of carbon, nearly twice what's in the atmosphere. No one expects all or even most of that to thaw. Until recently, researchers presumed permafrost would lose at most 10 percent of its carbon. Even that, it was thought, could take as much as 80 years.

But when the active layer stops freezing in winter, things speed up. The added warmth lets microbes chomp organic material in the soil—and emit carbon dioxide or methane—year-round, instead of for just a few short months each summer. And the winter warmth spreads down into the permafrost itself, thawing it faster.

"A lot of our assumptions are breaking down," said Róisín Commane, an atmospheric chemist at Columbia University who tracks carbon emissions by airplane. She and her colleagues have discovered that the amount of CO_2 coming off Alaska's North Slope in early winter has increased by 73 percent since 1975. "We've been trying to understand what's going on in the Arctic by relying on summer," Commane said. "But after the sun goes down—that's when the real story begins."

A few snowy winters don't make a trend; this past winter there was less snow in Cherskiy, and the soil cooled again considerably. Fairbanks also got little snow. Yet at some of Romanovsky's sites in Alaska, the active layer again retained enough heat to keep from completely freezing.

THE ZIMOVS FOUND SOMETHING DIFFERENT, WITH IMPLICATIONS BEYOND THE ARCTIC: A WINTERTIME THAW.

"This is truly amazing," said Max Holmes, deputy director of Massachusetts's Woods Hole Research Center, who has studied the carbon cycle in both Alaska and Cherskiy. "I've largely imagined permafrost thaw as a slow and steady process, and maybe this is an odd five-year period. But what if it's not? What if things change much more quickly?"

AND WHAT IF THE CHANGE becomes self-reinforcing—as it already is, for example, in the case of Arctic sea ice? Sea ice reflects the sun's rays, keeping the ocean below it cold. But as sea ice melts, the dark ocean absorbs that heat, which then melts more ice.

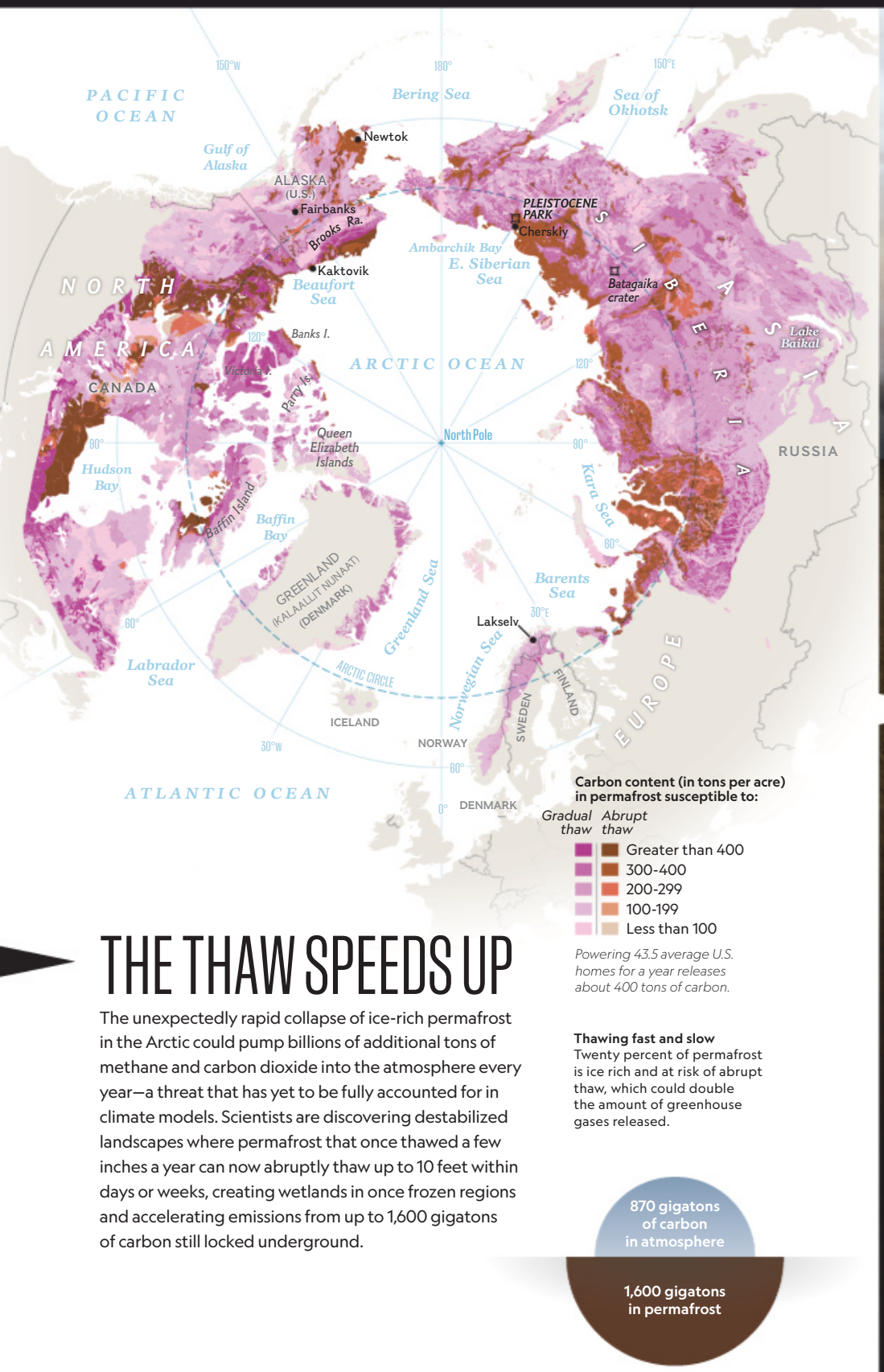
As a rule, the tipping points at which such feedback loops kick in are tricky to predict. "We know there are thresholds we don't want to cross," said Chris Field, director of Stanford University's Woods Institute for the Environment. "But we don't know precisely where they are."

With permafrost, there's just too much we can't see. It covers an area more than twice the size of the United States, inhabited by half as many people as New York City, in some of the world's least accessible terrain. Little of it is monitored directly. Scientists instead study





The valley of the Alatna River, which flows south out of Alaska's Brooks Range, has become a corridor for wildlife moving north into the warming Arctic. Beaver numbers are booming, and their ponds—several are visible on the far side of the river to the left—will hasten permafrost thaw.



Powering 43.5 average U.S. homes for a year releases about 400 tons of carbon.

THE THAW SPEEDS UP

The unexpectedly rapid collapse of ice-rich permafrost in the Arctic could pump billions of additional tons of methane and carbon dioxide into the atmosphere every year—a threat that has yet to be fully accounted for in climate models. Scientists are discovering destabilized landscapes where permafrost that once thawed a few inches a year can now abruptly thaw up to 10 feet within days or weeks, creating wetlands in once frozen regions and accelerating emissions from up to 1,600 gigatons of carbon still locked underground.

Thawing fast and slow
Twenty percent of permafrost is ice rich and at risk of abrupt thaw, which could double the amount of greenhouse gases released.

JASON TREAT, MATTHEW W. CHWASTYK, AND RYAN WILLIAMS, NGM STAFF
SOURCES: DAVID OLEFELDT AND OTHERS, *NATURE COMMUNICATIONS*, 2016; MERRITT TURETSKY AND OTHERS, *NATURE*, 2019; RÓISÍN COMMANE, COLUMBIA UNIVERSITY; TED SCHUUR, NORTHERN ARIZONA UNIVERSITY; EPA

SCENES OF THAWING

BURNING TUNDRA
Tundra fires, once rare, are becoming more common as a warming climate greens the Arctic. Fires thaw the top layer of soil and rapidly degrade the permafrost below.

A LANDSCAPE REVOLUTION

As ice buried within frozen ground melts, the meltwater moves through the permafrost, thawing it further and causing the ground above it to slump. Ponds form and later drain, hastening the collapse of even more frozen soils. The process is called abrupt thaw, and it's accelerating the release of trapped carbon—and visibly changing the Arctic.

How polygonal permafrost forms—and thaws



The active layer freezes in winter, creating cracks deep in the soil.

Water fills in the cracks, which freeze and expand, forming ice wedges.

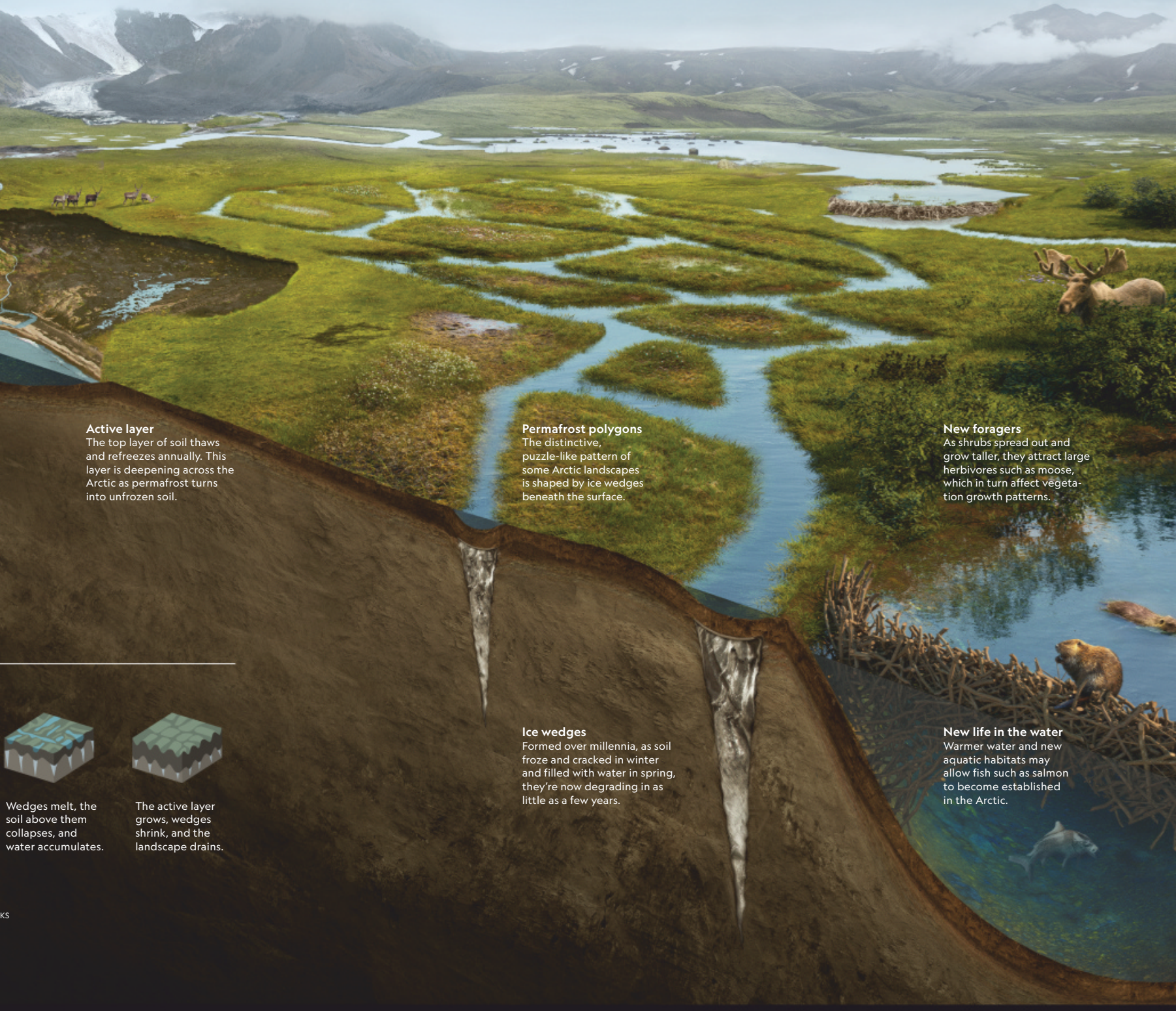
Growing ice wedges push soil upward, forming polygonal patterns.

JASON TREAT, RYAN WILLIAMS, AND EVE CONANT, NGM STAFF
ART: TOMÁŠ MÜLLER. SOURCES: KEN TAPE AND ANNA LILJEDAHL, UNIVERSITY OF ALASKA FAIRBAN

THAW SLUMPS
When permafrost thaws near a hillside or a stream or river, it can trigger a landslide. These so-called thaw slumps quickly expose more permafrost, rapidly accelerating further thawing.

SPREADING LAKES
Lakes that once froze solid are now partially liquid in winter and widening as permafrost thaws. The warmth allows microbes to feed on organic material year-round, releasing greenhouse gases.

BEAVER PONDS
A warming tundra has more and larger shrubs, which attract beavers. They dam up creeks, creating new ponds and lakes. That speeds up permafrost collapse and alters the landscape.



Active layer
The top layer of soil thaws and refreezes annually. This layer is deepening across the Arctic as permafrost turns into unfrozen soil.

Permafrost polygons
The distinctive, puzzle-like pattern of some Arctic landscapes is shaped by ice wedges beneath the surface.

New foragers
As shrubs spread out and grow taller, they attract large herbivores such as moose, which in turn affect vegetation growth patterns.

Ice wedges
Formed over millennia, as soil froze and cracked in winter and filled with water in spring, they're now degrading in as little as a few years.

New life in the water
Warmer water and new aquatic habitats may allow fish such as salmon to become established in the Arctic.

Wedges melt, the soil above them collapses, and water accumulates.

The active layer grows, wedges shrink, and the landscape drains.

KS



The ancient soils of Arctic permafrost, seen here in the wall of the Batagaika crater, hold the organic remains of leaves, grass, and animals that died thousands of years ago, during the Ice Age. All that carbon has been safely bound in frozen earth—until now.

PHOTOGRAPH MADE WITH ASSISTANCE FROM LUBOV KUPRIYANOVA



RIGHT

The Zimovs believe that large grazing animals helped maintain rich Arctic grasslands during the Ice Age, in part by fertilizing the grass. In hopes of bringing back the dry steppe—and also slowing permafrost thaw—they are now importing wild horses and other grazers to a site along a tributary of the Kolyma River. They call it Pleistocene Park.

BELOW

Nikolai and Svetlana Yaglovsky, an indigenous couple, still make a living hunting and fishing on the Kolyma near Cherskiy. Some of their neighbors have been forced to move into town; thawing permafrost is undermining riverfront houses and making the landscape harder to navigate.







small plots, track others remotely, and draw inferences about the rest—unlike Arctic sea ice, which can be measured in its entirety by satellite. "You can go online and track exactly what happened to sea ice," said permafrost expert Ted Schuur of Northern Arizona University. "With permafrost, we're barely looking. We barely have the tools to measure what's happening."

One type of permafrost has researchers particularly concerned: the 20 percent or so that contains immense deposits of solid ice. Some of that ice formed when water percolated down through soils and froze as it hit permafrost; some was created over thousands of years during Arctic winters, when the ground contracted and cracked into polygonal patterns. In spring, meltwater filled those crevices, which later refroze. Over time the buried ice grew into massive wedges enveloped by permafrost soil. Duvanny Yar is shot through with them.

Such a structure can unravel swiftly. When permafrost disintegrates, buried ice melts too. As water drains, it transports heat that spreads the thawing, and it leaves behind tunnels and air pockets. The ground sinks to fill those cavities, creating surface depressions that fill with rain and meltwater. The water deepens the pools and chews through their icy banks, until puddles grow to ponds and ponds become lakes. That causes more ground to warm and more ice to melt.

"Abrupt thaw," as scientists call this process, changes the whole landscape. It triggers landslides; on Banks Island in Canada, scientists documented a 60-fold increase in massive ground slumps from 1984 to 2013. It topples forests. Merritt Turetsky, an ecologist with Canada's University of Guelph, has tracked abrupt thaw in a black spruce forest near Fairbanks for the past 15 years. Flooding there, she has found, is destabilizing tree roots and trunks. Turetsky suspects all the trees in her "drunken forest" will tip over soon and get swallowed by new wetlands. "There are still little pockets of land, but you have to wade through some pretty wet spots to reach them," she said.

All permafrost thaw leads to greenhouse gas emissions. But standing water accelerates the threat. The gas that bubbles from the oxygen-deprived mud under ponds and lakes is not only carbon dioxide but also methane, which is 25 times as potent a greenhouse gas as CO_2. Ecologist Katey Walter Anthony of the University of Alaska Fairbanks has been measuring the methane coming from Arctic lakes for two decades. Her latest calculations, published in 2018, suggest that new lakes created by abrupt thaw could nearly triple the greenhouse gas emissions expected from permafrost.

It's not clear how much of this message has reached policymakers. Last October the IPCC unveiled a new report on the more ambitious of two temperature goals adopted at the 2015 Paris conference. The planet already has warmed by about one degree Celsius (1.8 degrees Fahrenheit) since the 19th century. Capping global warming at 1.5 degrees Celsius rather than two degrees, the report said, would expose 420 million fewer people to frequent extreme heat waves, and it would halve the number of plants and animals facing habitat loss. It also might save some coral reefs—and as much as 770,000 square miles of permafrost. But to achieve the 1.5-degree goal, according to the IPCC, the world would have to cut greenhouse gas emissions 45 percent by 2030, eliminate them completely

The village of Newtok, Alaska, population 380, is sinking as the permafrost beneath it thaws. On a summer bird hunt, four Yupik boys—from left, Kenyon Kassaiuli, Jonah Andy, Larry Charles, and Reese John—cross a flooded walkway.



by 2050, and develop technologies to suck huge quantities back out of the atmosphere.

The challenge may be even starker. The 1.5-degree report was the first time the IPCC had taken permafrost emissions into account—but it didn't include emissions from abrupt thaw. Climate models aren't yet sophisticated enough to capture that kind of rapid landscape change. But at *National Geographic*'s request, Katey Walter Anthony and Charles Koven, a modeler at the Lawrence Berkeley National Laboratory, made rough calculations that do add in emissions from abrupt thaw. To halt temperature rise at 1.5 degrees, they estimate, we'd have to zero out our own fossil fuel emissions at least 20 percent sooner—no later than 2044, six years ahead of the IPCC timetable. That would give us just a quarter century to completely transform the global energy system.

"We're facing this unknown future with an incomplete set of tools," Koven said. "The uncertainty isn't all on our side. There are a lot of ways things could turn out worse." There's more than one way to make new lakes, for example.

A FEW WEEKS AFTER LEAVING Siberia, Orlinsky and I took a raft trip through Alaska's Gates of the Arctic National Park with ecologist Ken Tape, a colleague of Walter Anthony's at the University of Alaska. A floatplane dropped us and river guide Michael Wald at Gaedeke Lake, in the central Brooks Range. From there we made our way south down the Alatna River. September sun danced on the water. Within a mile or so we found chewed sticks along the bank. We'd been on the river a week when we arrived at a 38-acre lake that hadn't been there before. At its center was an enormous beaver lodge.

Tape has been using aerial and satellite photographs for years to track how plants and wildlife are changing in Alaska—and how that might affect permafrost. As permafrost thaws and the growing seasons lengthen, the Arctic is greening: Shrubs in Alaska river plains, for example, have nearly doubled in size. (While vegetation growth will take up more carbon, a 2016 survey of experts concluded that Arctic greening won't be nearly enough to offset permafrost thaw.) The vegetation is drawing animals north.



The crumbling permafrost cliffs at Newtok, on the Ninglick River near the Bering Sea, are now within a few dozen feet of some homes. The village is moving to a new site nine miles upriver—pioneering a process that many Alaskan villages may one day undergo.



With willows now tall enough to poke through snow, snowshoe hares can find winter food and hiding spots all the way to the Arctic Ocean. Typically forest dwellers, they've now colonized Alaska's North Slope, hundreds of miles from any real forest. Lynx, which prey on hares, appear to have followed. Both are probably traveling a trail blazed by moose, which also eat willows and now number roughly 1,600 along the Colville River, where they were absent before.

Those discoveries led Tape to search photographs for other tundra newcomers. "As soon as I thought about beavers, I seized on it," he said. "Very few species leave a mark so visible that you can see it from space."

In images from 1999 to 2014, covering just three watersheds, he spotted 56 new beaver pond complexes that hadn't been there in the 1980s. The animals are colonizing northern Alaska in earnest, moving at about five miles per year. Tape believes there are now up to 800 beaver pond complexes in Arctic Alaska, including the one with the massive lodge on the Alatna. Tape dubbed it Lodge Mahal.

It was quite a sight: a mound of branches and saplings, about eight feet high by 35 feet

across, plastered with mud and moss and sitting in a waist-high lake surrounded by marsh. The water had been diverted from the river by a series of dams. "That entire swamp around Lodge Mahal is new," Tape said. "If you went back 50 years, there'd be zero beavers here."

Tape and Wald had wanted to explore the Alatna in part because a guide who works for Wald had earlier found beaver-chewed wood along the Nigu River. The Nigu starts near Gaedeke Lake, the Alatna headwaters, but on the other side of the Continental Divide—and so it flows north into the Colville River and the Arctic Ocean. Along the Alatna, above Lodge Mahal, we found other ponds and abandoned dams. Tape now thinks that beavers are on their way to the North Slope, and that they're using the Alatna as a route through the Brooks Range. "We're seeing this expansion in real time," he said.

He can't prove that climate change is driving it; the beaver population also has been rebounding since the end of the fur trade, a century and a half ago. But in any case, the bucktoothed engineers could significantly remake permafrost landscapes. "Imagine if you were a developer and you said, I'd like permission to put three dams on every other stream in the Arctic tundra," Tape said. "That's what this could be like."

Tape has seen a preview. Southeast of Shishmaref, on Alaska's Seward Peninsula, photos of a tributary of the Serpentine River show no change at all between 1950 and 1985. By 2002 beavers had moved in and flooded the landscape. By 2012 some ground had collapsed and become wetlands. Permafrost was on its way out.

A few hundred beavers won't reengineer the Arctic. But the animals may be heading north in Canada and Siberia too, and they reproduce quickly. Argentina's experience is instructive: Twenty beavers were deliberately introduced in the south in 1946 in order to foster a fur trade. Today that population hovers around 100,000.



IN THE ZIMOVS' VISION OF the past and future of Arctic permafrost, wild animals also play a central role—but the beasts are bigger than beavers, and their effect on permafrost more benevolent. The herds of bison, mammoths, horses, and reindeer that lumbered across the Pleistocene steppes, Sergey Zimov has long argued, did more than just eat the grass. They maintained it. They fertilized it with their waste and packed it down, trampling mosses and shrubs and ripping out tree saplings.

Since the last ice age, those dry, rich grasslands have been replaced in eastern Siberia by damp tundra, dominated by mosses in the north and forests farther south. One key driver of that change, according to Zimov, was human hunters who decimated the herds of large grazers, by about 10,000 years ago. Without grazers to fertilize the soil, grasses withered; without grasses to soak up water, the soil got wetter. Mosses and trees took over. But if humans hadn't pushed the ecosystem beyond a tipping point thousands of years ago, there would still be mammoths grazing in Siberia.

Almost 25 years ago, on lowlands near Cherskiy, Zimov created a 56-square-mile demonstration project called Pleistocene Park. His idea was to bring large grazers back and see whether they would bring back the grasslands.



LEFT

For thousands of years, Inupiat villagers along Alaska's North Slope have hunted bowhead whales. A single whale can feed a community for much of a year if the meat and blubber are properly stored, which traditionally has been done in ice cellars dug into the permafrost. As the permafrost thaws, ice cellars are flooding.

BELOW

Josiah Olemaun, a young Inupiat whaler in Utqiaġvik (Barrow), Alaska, takes a breather while stacking whale meat in his family's permafrost cellar.





He and, eventually, Nikita fenced in wild horses and later trucked in yaks and sheep from Lake Baikal. This past spring Nikita hauled in 12 bison from Denmark, traveling 9,000 miles across Russia by truck and barge. In 2018 the Zimovs joined forces with Harvard University geneticist George Church, who thinks he essentially can clone a mammoth. The hope is that one day those now extinct beasts will be stomping around Pleistocene Park, thriving in the Anthropocene.

The park is the ultimate test of Sergey Zimov's hypothesis—and, he hopes, a hedge against future climate change. Grasslands, especially when snow covered, reflect more sunlight than does dark forest. Grazing animals tamp down deep snow, allowing heat to escape the soil. Both things cool the land. If wildlife could restore grasslands, it would slow permafrost thaw and thus climate change. To make a real difference, though, you'd need to unleash thousands of zoos' worth of animals across millions of acres of the Arctic.

The Zimovs say the evidence from their 36,000-acre park is promising. Even with only about a hundred animals, the park's grasslands



A polar bear inspects a car near Kaktovik, Alaska. Melting sea ice is driving more bears onto land in search of food—just as thawing and flooding ice cellars are forcing more Alaskans to store fish and meat outside.

stay substantially cooler than the ground in the surrounding area.

The gap between the Zimovs' ambitions and the reality of the park is unquestionably large. During a tour one afternoon, Orlinsky and I hiked soggy grasses to a stretch of marsh to watch the horses. A lone bison hid in the distance. Nikita loaded us onto an eight-wheel mini-tank and took us crashing through the willows. After a steep climb we plowed over some skinny larches. This is why he needs giant herbivores, Nikita said: "At the moment I don't have any animals which can kill those trees." He spends a lot of time raising funds, most recently in California, hobnobbing with the likes of former Governor Jerry Brown, just to keep this proof of concept going.

The concept has its critics. Some scientists dispute the Zimovs' estimates of how many large animals were roaming around Siberia in the Pleistocene, or insist that their theory of ecological change, both past and present, is too simplistic. Above all, most criticism seems leveled at the Zimovs' audacity. Max Holmes of Woods Hole, who knows them well, sees a spark of genius in their work. The Zimovs are "at the fringe," Holmes said, "but that's often where big ideas and big changes originate."

Outside Pleistocene Park, the modern world has responded to the warming Arctic with complacency. We've spent decades ignoring the evidence of climate change and hoping that things won't get too bad. We count on technological advances that seem always just out of reach. And we do this in spite of the fact that climate scientists—permafrost experts in particular—say all signs point to the need for urgent and even audacious action.

The Zimovs are different: They've spent their lives battling an unforgiving landscape that rewards bullheadedness. Is trying to save permafrost by restoring the Arctic steppe, they ask, really so much crazier than counting on humans to quickly retool the world's energy system? Maybe we need a little craziness.

"Fighting climate change needs multiple actions from multiple different fronts," Nikita said. Only if we combine them all can we make the future "not entirely miserable." □

Staff writer **Craig Welch**'s latest feature was about ecological change on the Antarctic Peninsula. Photographer **Katie Orlinsky,** based in New York City, has covered the Arctic for more than five years.

BY
HEATHER PRINGLE

UNCOVERING AN ARCTIC MYSTERY

IN 1845
SIR JOHN FRANKLIN
AND CREW SET
OUT TO CHART THE
NORTHWEST
PASSAGE.
THEN THEY
VANISHED.



H.M.S. *Terror,* one of two ships from the doomed Franklin expedition, was discovered in 2016 off King William Island in the Canadian Arctic. The small expedition boat seen here sank along with the *Terror* and rests on the seafloor a short distance from the ship.
THIERRY BOYER, PARKS CANADA

FOR CENTURIES the Northwest Passage seemed little more than a mirage. John Cabot urged his ships into the unknown in 1497 and 1498 to find it, but failed. Martin Frobisher, Henry Hudson, and James Cook searched icy northern waters for it, in vain. In May 1845 a celebrated British explorer and naval officer, Sir John Franklin, took up the quest to find a route between the Atlantic and Pacific Oceans through Arctic waters. With orders from the British Admiralty, Franklin and a crew of 133 sailed out from the Thames in two massive naval vessels, H.M.S. *Erebus* and H.M.S. *Terror,* each specially equipped for polar service. It was the beginning of the grimmest disaster in Arctic exploration.

On paper, the expedition seemed to lack for



little. The crew was young, tough, and seasoned. The ships, sheathed in iron, bristled with the latest Victorian-era technology—from steam engines to heated water and an early daguerreotype camera. The vessels carried more than three years' worth of food and drink, as well as two barrel organs and libraries with some 2,900 books. Two dogs and a monkey kept the men company in their quarters.

But these small floating worlds were no match for the Arctic's frozen seas. On Admiralty orders, the expedition sailed to one of the most treacherous, ice-choked corners of the far north. By September 1846, both vessels were imprisoned in sea ice northwest of King William Island. They remained so for at least a year and a half of brutal polar cold.

By April 1848, 24 men were dead, including Franklin himself. The rest had abandoned the ships. In a terse statement stuffed into a cairn on King William Island, the expedition's new commander, Francis Crozier, noted that he and others were heading out on foot for the Back River, perhaps to find better hunting, or possibly hoping to reach a fur-trading outpost more than 700 miles away. It was Crozier's last known communication with the outside world. (More than a half century later, in 1906, Norwegian explorer Roald Amundsen would be credited as the first to navigate the treacherous Northwest Passage.)

For years after Franklin's expedition stalled, search parties combed the region's coastlines,









Relics from the lost expedition include these, found in 1859 in an abandoned boat on King William Island: blue-tinted snow goggles, a chronometer used to determine longitude, and a book of Christian melodies. An 1878-79 search uncovered a British Navy boot on the mainland—the farthest known point reached by expedition crew.

NATIONAL MARITIME MUSEUM, GREENWICH, LONDON (ALL)

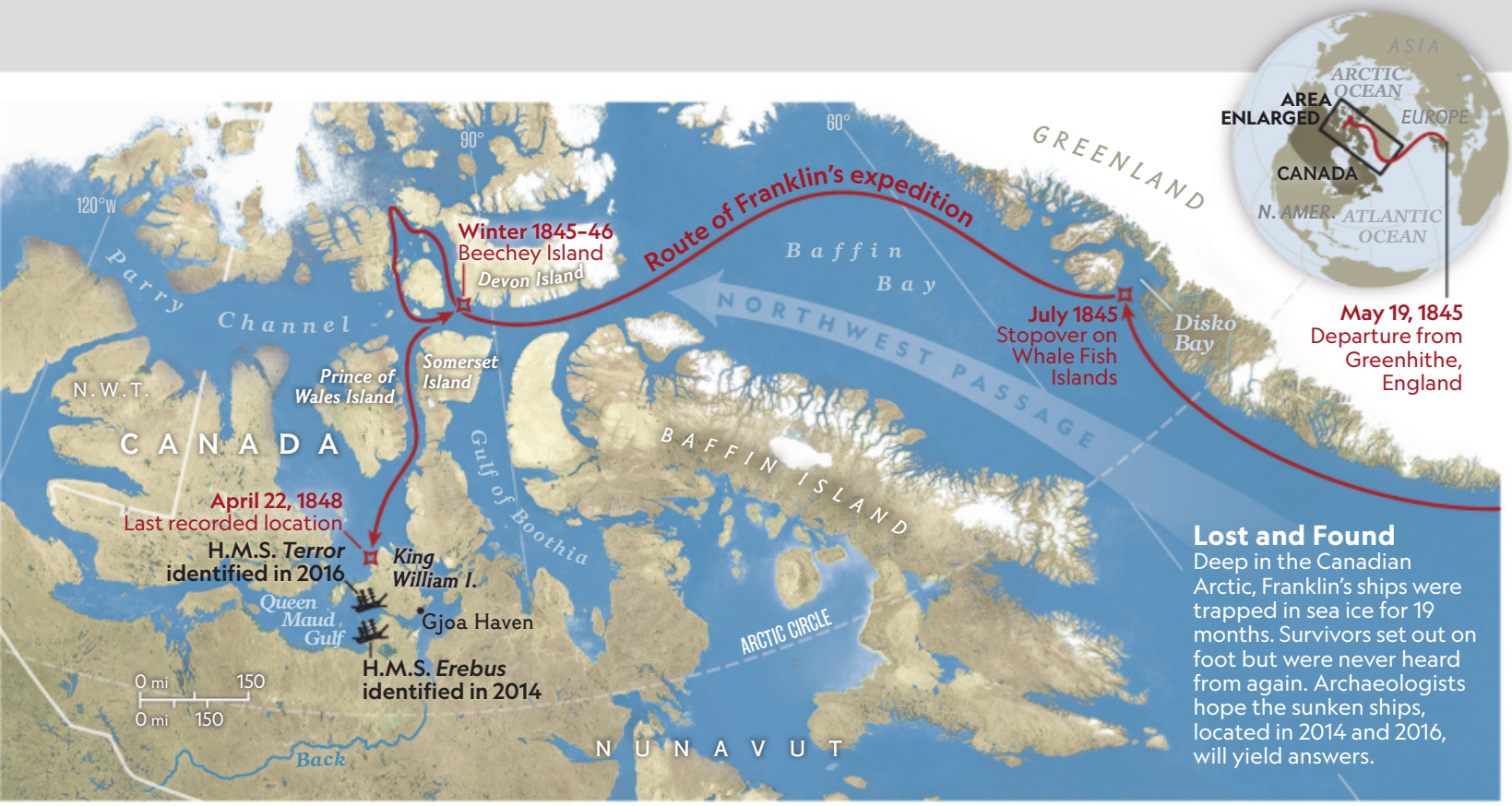
hoping to find survivors and, when all hope was gone, clues to the expedition's fate. They found deserted campsites, the bones of dead men, and hundreds of mementos, from fragments of cotton shirts to silver dessert spoons. Inuit hunters recalled seeing starving crewmen dragging heavy sledges along the ice, and later finding evidence of cannibalism. The British public was reluctant to believe it, and the final days of the Franklin expedition remained the subject of enduring fascination and mythmaking.

Then, in 2014, *Erebus* was discovered in relatively shallow water south of King William Island, almost exactly where historical Inuit testimony had placed it. Two years later, *Terror* was located at the bottom of a large bay after Inuit Canadian Ranger Sammy Kogvik led researchers to the area. *Terror* is so well preserved, says Parks Canada archaeologist Ryan Harris, that it resembles a ghost ship: "It just beggars the imagination what might lie inside."

A second research team, supported by the government of the Canadian territory of Nunavut, is now sifting through other important clues found on land. Led by Douglas Stenton, an archaeologist at the University of Waterloo in Ontario, these scientists are mapping the sites where Franklin crew members pitched tents, downed rations, and huddled beneath blankets and bearskins. By studying these locations and analyzing the human remains and artifacts recovered from them, Stenton and his colleagues hope to shed new light on the expedition's final tragic days.

ON A COLD, BLUSTERY day in the Arctic hamlet of Gjoa Haven, Kogvik recalls the joy of seeing *Terror* appear for the first time on a sonar screen. Like most Inuit in the region, Kogvik had heard stories about the lost expedition. He also had one of his own. While out fishing with a friend along the west coast of King William Island, he had once seen a big wooden pole sticking above the water. He thought it could be a ship's mast, so in September 2016, Kogvik guided a team from the Arctic Research Foundation, a Canadian nonprofit, to the area. After hours of searching the seafloor with side-scan sonar, Kogvik and his colleagues found *Terror,* about 80 feet underwater. "Every one of us was giving high fives," he recalls.

Today Parks Canada archaeologists are planning to excavate both Franklin ships, but *Erebus* is their priority. Harsh Arctic conditions now



Lost and Found
Deep in the Canadian Arctic, Franklin's ships were trapped in sea ice for 19 months. Survivors set out on foot but were never heard from again. Archaeologists hope the sunken ships, located in 2014 and 2016, will yield answers.

threaten the vessel. Sea ice has scoured the stern and crushed the area where Franklin had his cabin, entombing or scattering its artifacts.

More haunting still are the conditions aboard *Terror*. Thick sediment mantles the upper deck, but the ship's wheel, helm, and bulwarks look eerily intact. Windows and hatches, mostly unbroken, still seal the contents of the cabins.

Studies and excavations at the two wreck sites are expected to take years, and archaeologists hope to settle a long-standing controversy. Historians have assumed that most of Franklin's men died in 1848 on the foolhardy quest to the Back River. But in the 1980s, David Woodman, a retired mariner and history writer based in Port Coquitlam, British Columbia, analyzed the reports of Inuit witnesses. According to these accounts, few of Franklin's men died on the trek. Instead many returned to the ships after Crozier wrote his note, and managed to sail farther south. When the two vessels finally sank, the castaways survived on salvaged provisions and occasional hunted game, until the last man died in the early 1850s.

But the accounts given by some 30 Inuit witnesses contained many ambiguities and contradictions, in part because of translation problems. So the Parks Canada team hopes to recover written records from the shipwrecks, such as logs or personal journals, to help reveal what went wrong with the expedition.

IN BRITAIN, families of the dead men were left to wonder about their sons and husbands and how exactly they met their end—questions that linger among many descendants today. And some relief may be in sight. Stenton and his team have taken samples from skeletal remains and sent them to Lakehead University in Ontario. Geneticists there successfully extracted DNA from the remains of 26 crew members. Now Stenton is gathering DNA samples from living descendants. By comparing the historical and modern DNA profiles, he and his colleagues hope to identify some of the bodies by name.

Moreover, the Parks Canada team may add to these identifications. Historical Inuit witnesses reported boarding one of the ships and finding a crewman's body lying on a floor. The underwater archaeologists have yet to encounter any human remains, but if skeletons or bones turn up, the team will consider DNA testing.

For the first time in more than a century, hopes are high that the story of the lost expedition will be told. The optimism is bringing a new sense of opportunity to remote Gjoa Haven, where young Inuit are landing jobs to watch over and protect the Franklin wreck sites from looters. And officials are drawing up plans to expand the local museum, so it may one day house and display finds from the fabled Franklin ships.

"Tourists are already coming here," Kogvik says proudly. And enticed by the icy wonders of the Northwest Passage and the famous story of Franklin and his men, "more will be coming next year." □

Canadian science writer **Heather Pringle** specializes in archaeology. Her forthcoming book on the Vikings will be published by National Geographic in February 2021.

KATIE ARMSTRONG, NGM STAFF. MODERN SATELLITE IMAGERY. SOURCES: PARKS CANADA; NATIONAL MARITIME MUSEUM, GREENWICH, LONDON

BY **JENNIFER KINGSLEY**
PHOTOGRAPHS
BY **ESTHER HORVATH**

EYES ON THE ICE

IN GREENLAND, RESEARCHERS FROM AROUND THE WORLD DOCUMENT THE WARMING ARCTIC—AND SHARE A SENSE OF COMMUNITY.



A helium-filled balloon is tethered at Flyger's Hut, about a mile southeast of Station Nord. The instrument will measure air turbulence, solar and terrestrial radiation, and black carbon from the lowest layers of the atmosphere—lower than an airplane can fly safely.





The summer evening is warm enough for the soldiers to sit outside with their shirts off.

One person is playing the guitar, another is reading. There's a relaxed, vacation vibe despite the location: 575 miles from the North Pole at a Danish military outpost in northeastern Greenland called Station Nord. The generator hums in the distance, and occasionally the two Greenland dogs begin to bark. The sun circles the Arctic sky.

The day-to-day operations of this base are mostly scientific. The Arctic is warming faster than any other place on Earth, and for researchers studying the impact of climate change, the base has the advantage of being remote—at nearly 82 degrees north and inside the world's largest national park—and accessible, because of its runway. It's no exaggeration to say that



Soldiers and researchers come together for a pig roast and game night. Competitors try to put a jousting lance through a small ring while a colleague pushes them on a cargo bike. As the night goes on, the ring gets smaller, and teams seek to distract their opponents.

MAP: MATTHEW W. CHWASTYK, NGM STAFF



whatever happens here affects the whole world: The Arctic is part of a global cooling system, and as rising temperatures accelerate the loss of sea ice, that system is breaking down. This is a perfect place for visiting researchers from around the world to gather data from the ice, sea, and atmosphere to measure changes over time—data that scientists hope will help them predict what's in store for the planet.

There aren't many places where you can wake up in a bunkhouse, have coffee, and then step into one of the planet's most extreme environments: Whiteouts, extreme cold, fog, and months of winter darkness are par for the course. During spring the temperature can dip below minus 30 degrees Fahrenheit, and by summer there's so much dust from blowing winds, it coats your teeth.

Station Nord also has a political purpose, which is why it's run by soldiers. Denmark has an internationally recognized sovereignty claim over this region but must demonstrate its presence here in order to uphold it. For the six specialists who live here—all soldiers in the Danish military, almost always men—Station Nord is home for a 26-month posting.

The station, which began primarily as a weather center in 1952, is essentially a small village with its own airport. There are more than 25 buildings, including bunkhouses, workshops, a generator shed, a kitchen, and a community center. Single-purpose structures

Lunch next to an iceberg on the sea ice is a hurried affair with temperatures below minus 30°F. Researchers rehydrate freeze-dried meals with hot water from a thermos and eat quickly, since the food turns cold in just a few minutes.





Jesper Juul Hansen, station leader at the time, says hello to Trille, one of the station's two Greenland dogs, outside the kitchen building, while researcher Tobias Donth looks on. The dogs are critical to soldiers' emotional well-being. "They give something," Hansen says. "They are so happy, always."

are spread out as a precaution against fire.

The campus is extensive enough to provide the infrastructure required to produce world-class science in a hazardous—and beautiful—environment. The soldiers clear runways, fuel airplanes, clean barracks, secure food shipped on cargo planes and retrieve water from a glacial lake nearby, and repair equipment. In winter the six of them—eight if you count the dogs—are alone for months, with a satellite connection that allows for basic email and text messages. Everyone gets a monthly call allowance. It's more work to shut the station completely during winter than to keep a skeleton crew to look after things.

From spring through fall, they host a rotating, international community of up to 60 people—teams of scientists, support workers, pilots, engineers, and military personnel.

The community has a culture of its own. If you are late for a communal meal, you are expected, at some point, to bake a cake for everyone. Every Saturday night is feast night, with a three-course meal. Everyone must wear a necktie or a skirt, and if you didn't bring one, as most first timers don't, you may use the station facilities to make one out of anything you can find, including wood, electrical wire, books, or tea bag wrappers; real examples are exhibited on the kitchen wall.

On Saturdays, soldier Mads Adamsen says, you feel like you're "coming home to your family from another place."



The hours are long, the logistics complex. With rapidly changing conditions—sun to snow in an hour sometimes—there's always some risk.

Thomas Krumpen, a senior scientist from Germany's Alfred Wegener Institute, leads aircraft-based surveys that measure, among other things, the summer thickness of sea ice, which is very difficult to calculate from satellite imagery. To do this, a modified DC-3 aircraft flies over the ice at an altitude of 200 feet while trailing a sensor on a cable just 50 feet above the ice surface. The job takes so much concentration, Krumpen says, "I find it hard sometimes to really just look outside the window and enjoy or observe what I am actually surveying."

These flights demonstrate the effort it can take to answer simple questions: How thick is the sea ice? How reflective is the snow?

Observations from the flights feed into climate models, complex computer programs that use equations and thousands of pieces of data to project what will happen as the climate continues to change. Information about the Arctic is essential to predicting global consequences such as temperature increase and sea-level rise.

"We need to look into the future in order to tell people what are the consequences we are facing," Krumpen says. Other researchers fly weather balloons, dig pits to sample the snow, or peer at their instruments all night with a sled dog nearby to warn them of polar bears. Little by little, they glean information that will help answer the biggest question of the climate change era: What is going to happen to our planet? The answer is both politically and scientifically contentious, and it takes many years of data from many locations to draft an answer.

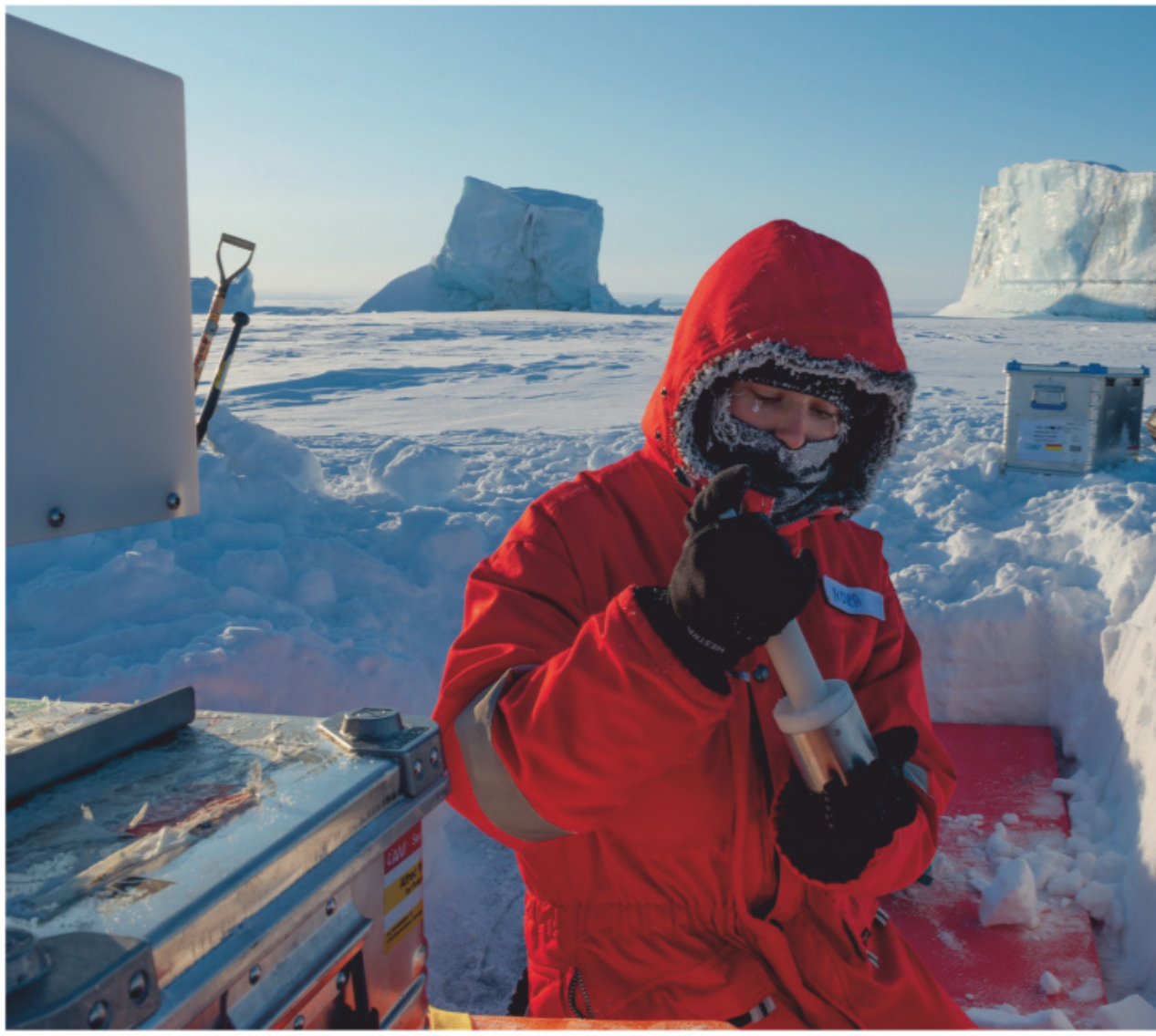
For this region of the world, none of it could happen without station specialists such as Jesper Juul Hansen, who makes it sound simple. "We just did our part so that they could do their part," he says.

The work takes its toll. Nora Fried celebrated her 25th birthday at the station as a research assistant in 2018. Someday, "I have to explain to my children that we didn't do anything, although we knew that the Arctic would be ice free," she says. "I feel sorry for the Arctic."

One Saturday each summer, the soldiers organize an annual pig roast—the pig arrives by cargo plane—and a game night, including a jousting competition. Each team of two is given a three-wheeled cargo bike and a wooden jousting lance they must push through a ring hanging from a rope. The ring gets smaller with each round, and competitors try hard to distract each other. The silliness brings people together, and pushes those at the station toward feeling like a community.

"You realize that you are relying on people all the time for your life to work out, right, but you don't see it back home," Hansen says. "You don't really have that feedback where you see the fruits of your labor reflected in other people." But up in the Arctic, he says, "it's very obvious." ▯

Jennifer Kingsley's last story for *National Geographic* was about women in the Chukotka region of Russia. **Esther Horvath** is a Germany-based photographer who documents polar regions.



TOP LEFT

Research assistant Nora Fried uses a handheld IceCube, an instrument that measures the specific surface area of snow particles on the sea ice. The structure of snow is critical to how much light it absorbs or reflects, and therefore how it contributes to atmospheric warming.

TOP RIGHT

A temporary tent provides shelter for researchers working on a meteorological experiment that required 24-hour monitoring. Because polar bears are a constant concern outside of the station boundaries, the camp always has a Greenland dog to keep watch.

BOTTOM LEFT

Preparing for guests can be a lot of work for the six soldiers who run Station Nord. Snowdrifts sometimes threaten to bury entire buildings.

BOTTOM RIGHT

Hansen helps researcher Helge Goessling (right) brush up on his rifle skills. No one is permitted to leave the station perimeter without a firearm for protection against polar bears.













The *Polar 5* research plane, a modified turbine DC-3, is a key piece of equipment that visits the station three or four times a year. It tows a torpedo-like sensor that uses laser and electromagnetic technology to calculate sea ice thickness.







IN A 30-HOUR ENCOUNTER WITH A PACK OF ARCTIC WOLVES, OUR WRITER GAINED A NEW APPRECIATION FOR THESE PREDATORS OF THE TUNDRA.

ALONE WITH WOLVES

BY **NEIL SHEA**

PHOTOGRAPHS BY **RONAN DONOVAN**



A yearling male, known to our film crew as Gray Mane, walks ahead of a pack of arctic wolves in search of prey. This hunt lasted almost two days and covered some 65 miles. Filmmakers were able to follow the pack closely during the summer of 2018.

PREVIOUS PAGES

Wolves pick at the remains of a muskox. To get this image, photographer Ronan Donovan placed a camera trap inside the carcass. The pack returned to feed on and off for a month.

IN THE BLUE LIGHT OF AN EARLY ARCTIC morning, seven wolves slid across a frozen pond, yipping and squealing and chasing a chunk of ice about the size of a hockey puck. ¶ The pond was opalescent at that hour, a mirror of the universe, and the wolves also seemed otherworldly in their happiness. Back and forth across the pond they chased, four pups scrambling after the puck and three older wolves knocking them down, checking their little bodies into frozen grass at the shore. In my notebook, in letters made nearly illegible by my shivering, I wrote the word "goofy." ¶ The largest wolf, a yearling male, was a bully at 70 pounds or so. The smallest, the runt of that year's litter, was hardly bigger than a throw pillow, her eyes lined in black. A pair of ravens sailed overhead, and apart from their jeering, there was no sound on the tundra but the voices of wolves and the click of claws on the ice. Eventually the puck skittered into the grass, and the largest pup chased it down and chomped it to pieces.



A pup bites at a feather while another nuzzles the pack's aging matriarch, White Scarf (far right). After the last known kill she was part of, White Scarf made sure the pups ate first and later disappeared out on the tundra. One of her daughters tried to take over as the new leader.

KINGDOM OF THE WHITE WOLF
Watch photographer Ronan Donovan as he tracks and observes arctic wolves. The three-hour special airs on August 25 starting at 8/9c on Nat Geo WILD.



The rest stood watching, heads cocked to the side. As though they were stunned by the rudeness of it. Then, one by one, the wolves turned and looked at me.

This is a difficult sensation to describe—the lock-on moment when a group of predators sights you and holds your gaze for a dozen heartbeats. Humans aren't usually the objects of such appraisal, though my body seemed to recognize it way down beyond thought. I shivered again, and this time it wasn't from the cold. However playful they'd appeared a few minutes before, these were wild wolves. Their white coats were dark with gore. The carcass they'd been feeding on, a muskox many times larger than me, lay nearby with its rib cage cracked open, the bones splayed like a fan against the sky.

The wolves watched me silently, but they were talking to each other with flicks of their ears, the posture of their tails. They were making decisions. And after a few moments they decided to come closer.

THERE IS PROBABLY NO other place on Earth where this would happen. It's why I traveled to Ellesmere Island, high in the Canadian Arctic, joining a documentary film crew. The landscape is so remote, and in winter so cold, that humans



A 12-week-old pup stretches in the September twilight after feeding on a fresh muskox carcass. Now big enough to travel, the pups must gain weight and learn crucial survival skills—including hunting and avoiding other packs—before winter sets in.

WOLVES OF THE FAR NORTH

Arctic wolves live only in Canada's high Arctic islands and along stretches of Greenland's coastline, but they are closely related to the gray wolves found in the Rockies, much of Canada, and parts of Europe. Scientists are unsure how many Arctic wolves inhabit this range today.



MATTHEW W. CHWASTYK, NGM STAFF; SCOTT ELDER. SOURCES: NUNAVUT DEPARTMENT OF ENVIRONMENT, WILDLIFE RESEARCH SECTION; INTERNATIONAL UNION FOR CONSERVATION OF NATURE; U.S. FISH AND WILDLIFE SERVICE; USGS; RONAN DONOVAN

rarely visit. A weather station named Eureka is pinned to the west coast and maintains a year-round staff of about eight. Otherwise the nearest community (population 129) is Grise Fiord, 250 miles to the south. A thousand miles past that stands the nearest plant you would actually recognize as a tree.

What this means is that the wolves in this part of Ellesmere—the same species of gray wolf *(Canis lupus)* that lives in the northern Rockies, much of Canada, and small, scattered populations across Europe and Asia—have never been hunted, never chased away by development, never poisoned or snared by ranchers. Cars don't crush them; fickle legislation doesn't protect them one year and endanger them the next. Only a few scientists have ever studied them. Even among the Inuit I know, whose ancestors have inhabited this region for millennia, these wolves stand apart.

This isn't to say that the Ellesmere wolves never encounter people. Beginning in 1986, the legendary biologist L. David Mech spent 25 summers observing wolves here. Weather station personnel see them often, and large groups of wolves have been reported wandering through the station grounds.

And my friends on the film crew had essentially embedded with the pack I came to know for a few weeks, using ATVs to follow their relentless movement.

Did this human contact somehow make them less wild? Is the measure of an animal's wildness equal to the distance it keeps from humans? The Ellesmere wolves are separated from their relatives living on much tamer landscapes to the south, such as Idaho or Montana, by far more than distance. Up here, wolves were never driven to the edge of extinction by humans. Here they live so far beyond the human shadow, they aren't necessarily frightened of it, of us. To visit them is to surrender control and enter another world.

TOP RIGHT

The pack, desperate for prey, scours Greely Fiord for muskoxen and arctic hares. When the fiord freezes in winter, their hunting territory extends beyond the distant mountains.

BOTTOM

The wolves visited a Canadian military outpost, ignoring the muskox skeleton hung up by the staff. Instead, the pack moved on to hunt arctic hares in the grass around the airfield.







The wolves keep three male muskoxen in their sights. To kill one of these animals, which can weigh up to 650 pounds, the pack must learn to cooperate. Muskoxen are one of the few prey animals that work together to form a defensive line. The wolves look for opportunities to isolate one muskox from the protection of the herd. These muskoxen deterred the threat.



A young muskox fended off the wolves for 20 minutes before going down. As One Eye (far left) struggled to bite and hold the calf's nose, the other wolves attacked from behind. This is how the yearlings learn to kill, generally targeting the young, old, and sick. The ravenous wolves sometimes begin to feed on their prey before it's dead.



After a feeding, the pack rests and digests the meal. Wolves live a feast-or-famine lifestyle. Most hunts are unsuccessful, and adults can go two weeks without eating. After a kill they gorge themselves, consuming up to 20 pounds of meat at once. It won't be long before they're on the move again.

ON THE FROZEN POND THAT day, the pack approached slowly, heads low, noses gathering scent. It was early September, 27°F. The brief Arctic summer had ended, though the sun still lingered in the sky each day for 20 hours or so. True night, the winter night that would last four months and see temperatures fall to 60 below, was still a few weeks away.

I was alone, unarmed. I would eventually rendezvous with my friends, but for now they were about five miles south. I sat on the ice, thinking that a few times in my life I had been this solitary, but I'd never been so vulnerable.

The wolves parted around me like smoke. Their winter coats were coming in. As they passed, markings that had distinguished them during our filming loomed into close-up view—the yearling male with gray hairs in his ruff, the female whose left eyeball had been punctured, probably during battle with a muskox. Black tips on the pups' tails that would soon turn white. I could smell the gravy of muskox blood they'd been rolling in.

The pups loped past at a distance, clumsy on their enormous paws. But the older wolves drew nearer. A bold female, probably two or three years old, walked up and stood at arm's length. Her eyes were bright amber, her snout darkened with old blood or perhaps burned trash from Eureka's dump, which the wolves were known to visit.

It was a jarring thought—she might have a mustache of melted plastic—but it vanished into the moment: A couple of feet away a wild wolf was staring at me. I decided to keep still and watched, enthralled.

I could hear gastric sounds, the wet squeeze of a roiling stomach. She looked me up and down, her nose ticking through the air as though she were sketching. Then she stepped nearer, and suddenly pressed her nose to my elbow. It was electric—and I twitched. The wolf leaped away and trotted onward, unhurried, glancing over her shoulder as she joined the rest of her family, busy burying their faces in leftover muskox.

It's tempting to think of wolves as we do dogs—companionable, limited, even cartoonish in their appetites or tendencies. Partly this is because they are visibly similar; partly it's because the comparison puts us at ease in the presence of a creature that for ages has been mythologized as a heedless killer. My encounter with the Ellesmere wolves erased any lingering thoughts of dogs. The bright-eyed female had examined me methodically. Calmly. She barely broke eye contact, and I glimpsed a radiant intelligence far beyond anything I'd known in another animal. There was an unmistakable sense that, in the depths of our coding, we knew each other.

I don't mean any sort of personal connection. She was not my spirit animal. I'm talking about genetic blueprinting, a species-level familiarity. Wolves are slightly older than modern humans, and so were fully formed when *Homo sapiens* emerged. It is no great stretch to believe that in our youth, we watched wolves hunt and learned from them, even while some became our pets.

Wolves, like humans, are also one of the most successful and versatile predators on the planet, and they live in family groups that are, by some measures, more similar to human families than even those of our closest primate relatives are. As climate change transforms the Arctic into a warmer, less predictable frontier, wolves will probably adapt the way we would—by exploiting new advantages and, if things go to hell, by migrating somewhere else.

SHORTLY BEFORE I ARRIVED on Ellesmere, the pack lost its mother. She had been maybe five or six years old, thin in the hips, slow to rise, and yet so firmly in charge that when my friends encountered her, in August, they didn't notice her frailty. She was likely mother to every wolf in the pack except her mate, a slender male with a bright white coat. He was the group's lead hunter, but she was its center. There seemed no question about who led.

The matriarch hadn't shown much interest in my friends and their cameras, though she allowed them intimately near her newborns, setting a tone that would carry over into the pack's tolerance toward me. The crew told me her final act, a week or so earlier, had been one of unexpected devotion.

After several failed hunts (wolf hunts often do not succeed), the pack managed to drag down a muskox calf weighing about 200 pounds. They hadn't eaten a large meal for a while, and the wolves gathered around, panting, exhausted, ravenous. But the matriarch stood beside the

carcass and fended off her older children, allowing only the four pups to eat.

The older wolves begged, whined, shimmied forward on their bellies, hoping for a mouthful. She held firm, snapping and growling, while the pups gorged, until their bellies swelled to the size of bowling balls. It was probably their first meal of fresh meat.

Eventually everyone was allowed into the feed. The animals stuffed themselves and fell into the wolf version of a food coma. At some point after that, the matriarch vanished. She never returned, and we never learned what became of her.

By the time I sat alone with the pack, they were still in disarray. It wasn't clear who would lead or whether the family would hunt well together. Winter was just weeks away, the starving time. The young bright-eyed female who'd nudged my elbow seemed eager to fill her mother's role, though she cared little for nurturing the pups. And during her first attempt at leading a hunt with the pack's elder male, she'd been flattened by a muskox.

A few hundred yards away I had watched as the big beast lowered its head and dug at her with its horns. I thought she'd been gored. Instead, she bounced up and skittered away, tail between her legs, and the hunt fell apart.

I SAT WITH THE WOLVES by the pond for nearly 30 hours, unable to tear myself away, unwilling for it to end. Whatever decisions or stress the pack faced, it was a happy time. They played, napped, nuzzled. I tried to keep them at a distance, but the wolves routinely wandered over to inspect me. I could smell their awful breath, hear their awful farts.

Their interest slowly faded, but it was so cold that every hour I was forced to stand and do a warm-up session of shadowboxing and jumping jacks. My flapping and panting always lured the wolves back. They would surround me, cock-eyed and curious, and they must have sensed I was nervous.

At a certain point, I set up a tent a distance away to get a few hours of sleep. While I was off melting ice to make drinking water, the one-eyed female approached and surgically slit open the tent. She hauled all of my possessions onto the barren ground, arranged them in a neat row, then ran off with my inflatable pillow.

Eventually, the wolves lay down, and the pups piled together in a downy mess. While they slept, I wandered. The migrant birds had flown south; foxes and ravens were silent. Strands of muskox hair, shed during the summer and smelling sweet as fresh-cut grass, streamed across the plain. Here and there ancient muskox skulls sank into the soil, the thick bone yellowed with lichen, the horns curling toward the sky. I felt like a trespasser drifting through the rooms of an empty house.

THE BRIGHT-EYED FEMALE WOLF LOOKED ME UP AND DOWN. METHODICALLY. CALMLY. SHE BARELY BROKE EYE CONTACT.

Hours later, the pack awoke and gathered in their usual post-nap huddle, with lots of face licking and tail wagging. It went on like this for a while, love at the end of the Earth, until the older wolves trotted off, heading west toward prime hunting ground, leaving the four pups alone with me. It seemed to confuse them, and me. This was not necessarily trust, more like nonchalance. I was neither prey nor threat but some third thing, and the older wolves understood this.

I can't tell you which members of the family survived winter, or whether they learned to hunt together again. Odds are good they did, just as odds are poor that all the pups lived. After the last of the older wolves dropped out of sight that day, the pups decided to get up and lope after them. I followed, and soon all five of us were lost. We wandered for an hour, and then along some nameless ridge, the pups sat down and began to howl, their little voices tumbling over the rocks. □

Author **Neil Shea** and photographer **Ronan Donovan** were part of a team of filmmakers who documented Ellesmere Island's arctic wolves for National Geographic WILD.

STORY AND
PHOTOGRAPHS
BY **ACACIA JOHNSON**

BEFORE IT MELTS

AS ICE THINS IN THE CANADIAN ARCTIC, THE INUIT USE CAMPING TRIPS TO TEACH THE YOUNG HOW TO LIVE OFF THE LAND—AND PRESERVE THEIR CULTURE.

When sea ice ages, the salt sinks into the ocean, leaving fresh, drinkable water on top. Charlotte Naqitaqvik collects a teapot of water at her family's hunting camp in Nuvukutaak, near the community of Arctic Bay in northern Canada.







IN THE SPRING, WHEN ANIMALS MIGRATE NORTH and the sun never sets, Inuit children join their families on weeks-long camping trips across Canada's Arctic. They're taught hunting skills and cultural values passed down for more than 5,000 years. In the past three decades, multiyear ice, the thickest (and oldest) type that supports the Arctic marine ecosystem, has declined by 95 percent. Elders no longer can predict safe travel routes on thinning ice, and animal migration patterns are changing. The future of the ice—and those who live on it—is uncertain.



Wearing a parka sewn by her mother, Ashley Hughes spent her 10th birthday camping with friends and family at Ikpikittuarjuk Bay. Hughes took part in the Inuit community's annual ice fishing competition for arctic char.

Seal hunting is an essential part of life for the Inuit. The skin, like this one from a recent kill, will be turned into outerwear. Passing on knowledge of hunting and food procurement helps communities survive a changing climate.



NGM MAPS

IN THE PAST THREE DECADES, THE THICKEST (AND OLDEST) ICE THAT SUPPORTS THE ARCTIC MARINE ECOSYSTEM HAS DECLINED BY 95 PERCENT.



Tagoonak Qavavauq, an Inuit elder, teaches children how to make a bread called bannock on a school field trip. Ancestral knowledge about how to survive on the frigid land is disappearing with the elders. Many are determined to pass down traditions, particularly to children whose families no longer hunt or go camping. Learning how to live with limited resources is key to survival at a time when food insecurity and poor nutrition are increasing problems in Inuit communities.


JACK LINK'S
BEEF JERKY
Feed Your Wild Side

PASSING DOWN ANCESTRAL HUNTING AND SURVIVAL SKILLS IS SEEN AS CRUCIAL AT A TIME WHEN SUCH KNOWLEDGE IS DISAPPEARING.







ABOVE

Owen Willie, 18, hunts snow geese on his family's remote camp in the Canadian Arctic. Willie joined the camping trip shortly after his high school graduation and spent the spring tracking the goose migration.

RIGHT

Darcy Enoogoo, 36, and his wife, Susan, take off work each year to bring their children on seal hunting trips. The ringed seal has vitamin-rich meat, fat that burns well, and skin to turn into warm clothing.

OPPOSITE PAGE

Marie Naqitarvik, 30, wasn't taught extensive hunting or camping skills as a child. She learned after marrying a professional hunter. Now they hunt with their children on ancestral lands in spring.







THE IDEA BEHIND THE CAMPING TRIPS IS TO ENSURE THAT INUIT TRADITIONS WILL SURVIVE, EVEN IF THE ICE DOES NOT.

A break in the sea ice means a carefully orchestrated crossing for Olayuk Naqitarvik, pulling his grandson in a *qamutik*, or sled, packed with supplies for a family camping trip. Despite being ill and frail, Naqitarvik's wife, Martha, insisted on taking part to relay her deep knowledge of living off the land to the next generations.



TRAVEL PHOTO CONTEST

WEIMIN CHU

GRAND-PRIZE WINNER; FIRST PLACE, CITIES CATEGORY

WHO

Chu, 29, an engineer turned photographer, lives in Chongqinq municipality in southwestern China.

WHERE

Upernavik, a fishing village with about 1,000 residents, in northwestern Greenland

WHAT

A Sony ILCE-7RM3 camera, with a 24-105mm lens

Chu has been traveling to Greenland for several years, photographing its austere landscapes. This year he visited the village of Upernavik for the first time and spent days scouting photo locations. One evening at sunset, he settled on a slope near the airport where he could capture sweeping views of the town and unobtrusively photograph villagers. After making a few images in the dusk light, Chu adjusted his camera's aperture and ISO setting, hoping to freeze people's movements. Just then, a family emerged from their home, and Chu seized the moment. "It felt so harmonious," he says of the scene in his grand-prize-winning entry in the Travel Photo Contest. "The whole land was covered by white, cold snow, and the blue tint at dusk made it even cooler. But the light from the windows, streetlights, and the family of three made the world warm again."

See the other winning photographs from the 2019 National Geographic Travel Photo Contest at **natgeo.com/travelphotocontest.** And if you're ready to join the next competition, learn more at **natgeo.com/photocontest.**

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Utah Prairie Dog *(Cynomys parvidens)*

Size: Head and body length, 30.5 - 36 cm (12 - 14.2 inches); tail, 3 - 6 cm (1.2 - 2.4 inches) **Weight:** 0.6 - 1.4 kg (1.3 - 3.1 lbs) **Habitat:** Shortgrass prairie and grasslands of southern Utah **Surviving number:** Estimated at 8,000 adults in 2004

Photographed by Kevin Schafer

WILDLIFE AS CANON SEES IT

Family friendly. The Utah prairie dog lives, socializes and cooperates with its extended family in an elaborate network of tunnels and chambers, called a "town," excavated over generations. Each winter, family members cozy up together for long periods to hibernate. When out foraging for choice grasses, they take turns looking out for danger. But while families can often escape predators this way, they have no defense against habitat loss, plague and poisoning. The future has turned decidedly unfriendly.

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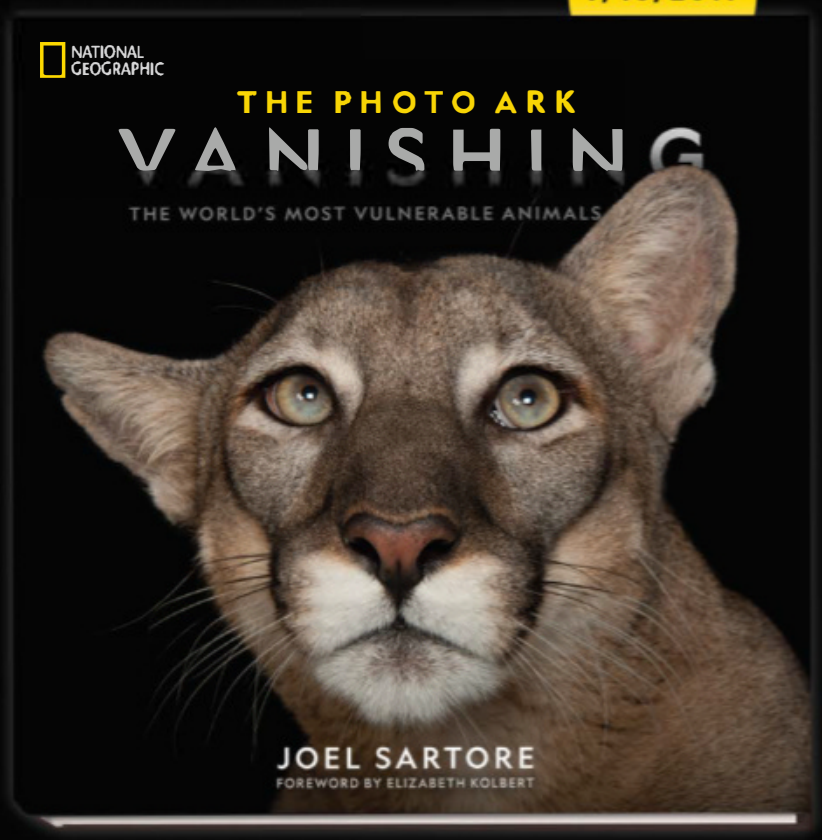
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"I WANT PEOPLE TO CARE, TO FALL IN LOVE, AND TO TAKE ACTION."

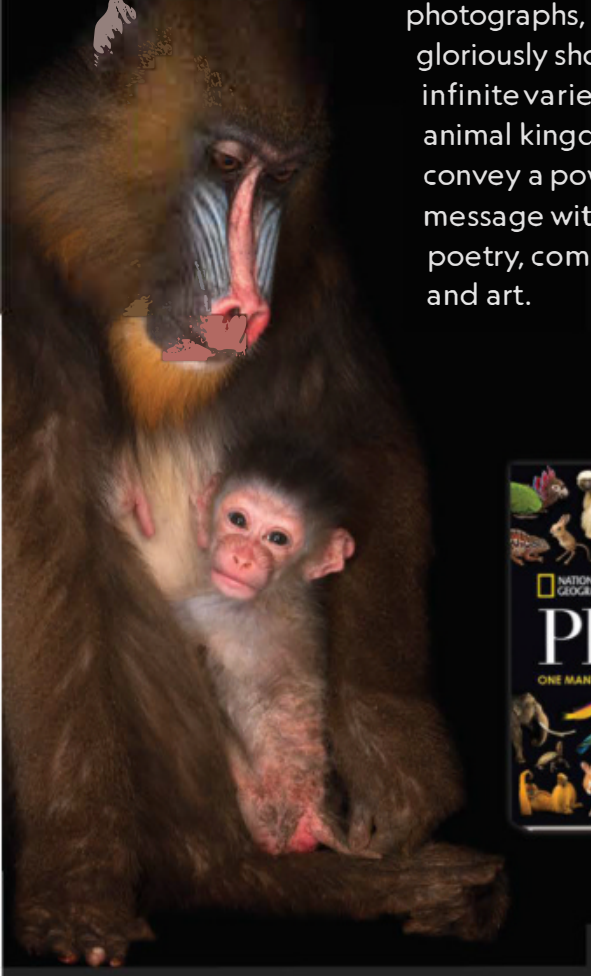
—Joel Sartore

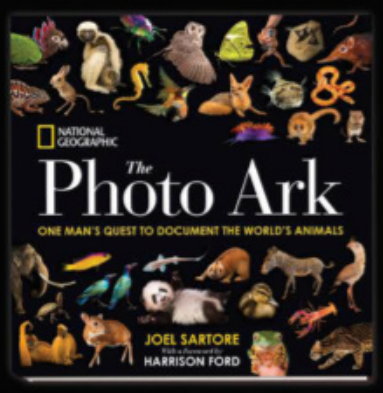
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